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WEST INDIAN BULLETIN

VOLUME XVII.

INTERNAL DISEASE OF COTTON BOLLS IN THE WEST INDIES. II.

BY

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INTRODUCTION.

In a previous paper[4] the writer has shown that in the West Indies the staining of developed cotton lint takes place in the green unopened boll, and with the exception of a varying proportion due to external boll diseases, is principally caused by direct infection of the lint with specific fungi, of which four species have been found[3], or, more rarely, with bacteria. Such infection was shown to take place, without apparent exception, through bug punctures, mainly made, under prevailing circumstances, by the cotton stainers (*Dysdercus* spp.).

The present paper discusses (*a*) the part taken by other bugs, especially the green bug (*Nezara viridula*) in injuring and infecting bolls, (*b*) the nature and significance of direct bug injuries which are not infected, and further, (*c*) records the occurrence of the fungi of internal boll disease in the seeds of numerous plants other than cotton.

The observations and experiments recorded were made during a visit of seven weeks' duration, from October 17 to December 9, 1917, to the island of St. Vincent.

The methods of study adopted, included (*a*) field observations of the relation between the prevalence of bugs and the amount of shedding, boll injury, and infection occurring; (*b*) close examination and record, lock by lock, of parcels of fresh green bolls obtained from selected typical districts; (*c*) a series of experiments in which bugs of various species, from known sources, were confined in cambric bags on uninjured bolls of known age; (*d*) examination of fruits of the wild and cultivated host plants of bugs for infection; (*e*) attempts by means of direct examination, dissections, and cultures to elucidate the carriage of infection by the bugs concerned.

CONDITIONS IN ST. VINCENT IN 1917.

In the previous paper on this subject (loc cit., p. 225), it was remarked that 'of all the islands St. Vincent has been subject to by far the heaviest and most regular losses from the disease under consideration' . . . 'The second picking, which with a first crop usually seriously reduced by rainy weather would often be the greater, reaches its maximum about the end of December. But the middle of December is about the time in St. Vincent when cotton stainers get completely out of control . . . . . In the conditions imposed by the heavy Autumn rainfall the control of stainers is vitally necessary to secure the stability of the St. Vincent cotton industry.'

The cotton season of 1917 was the first to test the effect of the application of the Cotton Stainer Ordinance (Saint Vincent), 1916[5], under which the Agricultural Department of the island carried out a campaign for the eradication of silk-cotton and mahoe trees, which are the principal alternative food-plants of Dysdercus.

The results came close to the satisfaction of the most sanguine expectations. During the period of the writer's visit, stainer infestation was confined to two very local instances, definitely traceable in the one case to a few trees, and in the other to exposed cotton seed which had escaped observation.

This condition made possible for the first time the study of the part taken in the damage to bolls by other bugs, previously masked by the effects of the more abundant cotton stainer. The island of Bequia, distant 9 miles from St. Vincent, afforded an opportunity of comparison with conditions in which the cotton stainer remained undisturbed, identical with those prevailing in St. Vincent in previous years. There were, moreover, on certain discontinuous areas in St. Vincent, infestations of green bugs, which according to local opinion, were unusually severe. (The suggestion was not wanting, among the peasants, that the severity of this previously unrecognized trouble was due to the removal of the stainer!)

Owing to the exceptionally dry weather which prevailed throughout the picking season, the interference of external boll diseases was reduced to a minimum.

The conditions relating to the occurrence of bugs in the field are being separately discussed by the Entomologist. The commonest species, *Nezara viridula* and *Edessa meditabunda*, known collectively in St. Vincent as bush bugs, have a wide range of hosts, but are most commonly found associated with leguminous plants, the latter especially with *Cajanus indicus*, the pigeon pea. On the estates most infested with these bugs there were heavy losses from the shedding or drying up of small bolls, and from direct bug injury. There was also a variable but rather low percentage of infection with internal boll disease.

A plot of cotton grown at the Botanic Gardens, near Kingstown, afforded exceedingly useful data, since it was found that the green bugs which infested it in spite of daily collections were not carrying infection.

At the Experiment Station, Kingstown, where large numbers of leguminous plants existed, bugs were very common. They included Nezara and Edessa, the two tomato bugs (*Leptoglossus balteatus* and *Phthia picta*), *Acanthocerus lobatus*, *Piezodorus guildingi*, and other species in small numbers. In spite of this abundance of bugs, the cotton bolls, as will be seen from figures given later, were not seriously affected. This was ascribed to the preference of the bugs for the other sources of food supply abundantly present, and to the action of egg-parasites in preventing their increase to a degree which would have caused them to extend their range.

In the small island of Batawia, from which stainers, and so far as could be seen, Nezara also, were absent, there was a crowded infestation of Edessa on pigeon peas interplanted with the cotton, and Leptoglossus was rather common on the cotton. The gross amount of damage was not large, and consisted of small stained spots on the surface of the lint, possibly attributable, as will be seen, to Edessa; and severe direct damage to some locks which could only be due to Leptoglossus. The amount of infection was small.

In Bequia, visited November 10-12, stainers were common and fast breeding up; Nezara, Edessa, and Leptoglossus were fairly common. The amount of damage was already large, and consisted of shedding, direct injury, and a larger amount of infection than had been seen elsewhere.

In all the places mentioned, except where stainers were present, the infestation tended to pass off, in some cases very quickly, during November and December. This is the great difference between 'bush bug' infestations and those of stainers. The former may be confidently expected to be reduced by the action of egg-parasites, the latter continue to increase without check to the end of the season.

THE NATURE AND SIGNIFICANCE OF DIRECT BUG INJURIES.

The Green Bug (*Nezara viridula*).

The detailed examination of forty green bolls (112 locks), picked at random from the uninfected Botanic Station plot

above referred to, and ranging in diameter from 18 to 29 mm. (average 23) gave the percentage results set out in the second line of Table I. The number of locks completely spoiled was thirty-two, and of locks with damage more or less incomplete, twenty-four. Three of the former were also infested with bacteria, otherwise no infection was detected in the examination with an adequate power of the microscope of one or more tufts from each injured lock.

The following examples are chosen to illustrate the nature of the injuries met with. They are supplemented, with regard to enclosed bugs, by the particulars given of Nos. 16 to 20 in Experiment II B.

EXAMPLES OF DIRECT INJURY FROM BOTANIC STATION PLOT.

No.	mm.	
1	28	Very heavily punctured and proliferated; seeds with many brown dots on testa. On the punctured seeds the lint is soaked down nto a transparent film, revealing the flesh colour of the seeds; it is not discoloured.
2	20	About 4 punctures, not proliferated; several seeds killed at an early stage and their lint browned. One older living seed with a brown patch of lint.
3	22	One lock fully punctured, others with 1 and 2 seeds respectively affected. Yellow felted lint over damaged seeds, more woolly than in (1) above.
4	24	Two proliferations: one seed with testa browned at large end and lint all more or less discoloured yellow. Remaining lint clean.
5	22	All three locks heavily punctured and proliferated; lint over punctured seeds reduced to a yellow translucent film.
6	20	Very heavily proliferated and lint generally water-soaked but not at all discoloured.
7	26	About 20 proliferations, some of which are 3 mm. in diameter. The seeds are uninjured and no damage whatever is visible on the well developed lint.
8	20	Very many and very large proliferations. Lint with corresponding depressions, very slightly discoloured.
9	23	About 5 punctures per lock, without proliferation, water-soaked lint over about 6 seeds; one small patch of stain. Each seed with red dots marking punctures which penetrate the testa but only show for a short distance below it.

The evidence obtained regarding uninfected punctures does not admit of a precise analysis of the relations between bug attack, the age of the boll, and the effect produced on seed and lint. Taking the bolls as they come from the open plot there are all gradations between locks with numerous punctures and no visible injury to lint or seed and those with a similar number of punctures in which the contents are completely ruined. Nor

does the occurrence or absence of proliferations supply an index to the resulting injury. The general conclusion reached is, that in this type of injury the severity of the effect depends principally on the extent to which the seed itself is injured, and the difficulty, in green bolls, of determining exactly how far this injury has gone, accounts for many of the apparent anomalies observed. In severe cases it is usually obvious that the development of the whole seed is stopped, and the endosperm shows signs of degeneration in the form of pasty consistency and slight discoloration, and ultimately shrivels. In other cases the seed attains its full size, the seed-coat blackens at the appropriate time, and the external appearance is normal; but when the seed is cut across the endosperm is found to be more or less unabsorbed, and the embryo within incompletely developed, or represented only by a vestige occupying a narrow cavity in the middle of the seed. The presence of such seeds contributes largely to the bad reputation in respect of germination of the second pickings instainer-infested districts, though W. L. Balls[1] has found that injury sufficient to prevent successful germination can be produced by bugs feeding on normal ripe seed.

It is easy to see, in a general way, how such injuries may affect the development of the hairs on the seed-coat, which constitute the lint; but it is not easy to say, without much further careful experimentation, where the injury begins and ends, or to establish more than a general correlation between seed injury and lint failure. One has to fall back, for the present, on description of the appearances met with in the boll. The earliest of these in connexion with young and damaged seeds is that best described as 'water-soaking,' i.e. in which, when the general surface of the lint mass in the lock is exposed by opening a green boll, it has lost over some or all of the seeds its natural brightness and opacity, and is usually soaked down on to the face of the seeds, the flesh colour of which shows clearly through the film. The amount of discoloration associated with this condition is very variable. It may be complete or absent. Commonly there is none when the boll is opened, but when left exposed by next day the film has dried light-brown, still allowing the form and colour of the seeds to show through. The seed mass, in completely injured locks, has then something of the appearance of a walnut kernel. When quite dry such locks are much shrunken owing to the shrivelling of the seeds, and the lint is reduced to a rusty-black felt or film. In partially damaged locks this type of injury is represented by large rusty-black felted spots over the face of each damaged seed. It serves to distinguish the latter from infected locks, that the lint between the spots or on adjacent undamaged seeds is quite white and clean.

In a fair number of examples there is a certain amount of staining visible when the seed mass is first exposed. Usually this is confined to lint in close contact with the seed, and even then may be localised in a spot or spots. In rarer cases, there is a general yellow or brown discoloration of the lint of a damaged seed. That this results from seed injury is inferred from the fact that the intermingled lint of adjacent unpunctured seeds is unaffected. Such a change may very well be due to oxidation of the cell contents in dead immature lint.

In addition to the general run of cases in which the injury is at once recognizable as being of the nature described above, there are occasional occurrences of locks in which, although no infection can be recognized by the methods of examination used, the effects of bacterial rotting are closely simulated. They were met with too rarely for their nature to be elucidated.

The negative effects of a large proportion of the visible punctures can best be explained on the assumptions: (a) that in many cases they did not reach the seed, (b) that older seeds are more resistant to the effects of punctures than young ones. More experiments are required on this point; in Series II the Nezaras confined on full-grown bolls caused so much infection that the effects of direct injury were obscured. The general evidence goes to show that the injury diminishes in relation to the age at which the boll is attacked.

With regard to shedding, a comparison of the results of experiments B and C, in Series II, fully bears out the conclusions reached from observation in the field as to the responsibility of Nezara for the shedding of young bolls. The experiments also go to show that under favourable weather conditions, when natural shedding was near the minimum, the limiting size of bolls shed owing to bug injury lies somewhere near 20 mm.

In Experiment II B, of twenty bolls eight to twelve days old (from the open flower) when first exposed to attack, eighteen were shed, with diameters ranging from 5 to 18 mm. When examined ten days from the time of exposure the three largest shed bolls (diameters of 16, 17, and 18 mm.) were still green, but beginning to crack, indicating that shedding had taken place about two days previously. The remainder showed degrees of dryness fairly corresponding with their size.

The shedding of Nos. 17 to 20 shows the result to be independent of infection.

Of the six bolls first exposed to attack when twenty to twenty-three days old, when they had attained their full size and had diameters of 23-27 mm., none was shed in spite of very severe injury.

S. C. Harland[2], in an analysis of cotton yield made in St. Vincent in 1916, found that shedding due to natural causes was at a maximum in bolls of 10 mm. diameter, and did not extend beyond those of 14 mm., whereas shedding due to internal injury increased up to 20 mm., after which it fell quickly to zero. His graph (Plate 12) may be further referred to on this point. As this study was made when weather conditions favoured shedding, it does not appear that bolls of more than 20-22 mm. are liable to shedding from this cause under any conditions.

The period of liability very rarely extends beyond the twenty-first day.

The Pea Chink (*Edessa meditabunda*).

The results of the trials made with this bug are set out in the final section of the tables, especially that referring to Experi-

ment II A. The injury was entirely of the direct type. The punctures referred to are those which were visible on the inner surface of the carpel. In the great majority of cases they were represented by minute dots or small rounded swellings, due to slight proliferation occurring under the tough inner membrane. The latter in very many cases was not visibly perforated. The proliferations recorded in the table are those of the usual type, in contact with the lint, the inner membrane in these cases having presumably been punctured by the bug. The stained patches, deep yellow in colour, were in all cases superficial, capable of being removed by a clip of the scissors, and not affecting the seed. They would be represented in the open boll by a brown knot or tuft of lint, such as was seen in bolls from Batawia where Edessa swarmed on pigeon peas interplanted with the cotton. It would take very many such tufts per boll visibly to affect the colour of the ginned lint. Their occurrence probably increases waste in spinning.

Considering the young state, and the period of exposure of these bolls, the results obtained in the positive cases do not support any idea that Edessa is a serious pest of cotton bolls. In no case did it cause any infection with internal boll disease, nor could the fungi of this disease be found on leguminous plants severely infested with this species unless other bugs were also present. It is however shown to be capable of some direct damage to the lint, and its presence in cotton fields is sufficiently undesirable to make interplanting with pigeon pea an unwise practice. There was an indication that this bug is best able to penetrate the bolls near to the tip.

THE LEAF-FOOTED BUG (*Leptoglossus balteatus*).

The direct injury which results from punctures made by this species is of the same nature and at least as severe as that produced by the green bug (Experiments D and F). The influence on shedding is probably about the same.

COTTON STAINERS (*Dysdercus* spp.).

Reference was made in the previous paper to the direct effects of stainer punctures, as seen in uninfected bolls. They were described as consisting of local damage to the young lint in the neighbourhood of a puncture, or more general damage to the lint of badly injured seeds.

Better acquaintance with effects of the latter type enabled some discrimination to be made between the results of direct injury and those of infection, where both occur in the same lock. In the examination of some sixty bolls obtained from Montserrat in January, representing the severest stage of infestation, it was found that about 60 per cent. of locks were so badly damaged in consequence of direct injury to the seeds that their infection with internal boll disease was of no practical importance. It is true that the seeds themselves were found in a number of cases to be infected, but this was not necessary for the production of injury sufficient to leave the lint undeveloped and worthless.

In the Bequia bolls, obtained early in December, at a time when stainers were fairly numerous but when the infestation would probably require some four to six weeks to become complete, the percentage of complete direct injury was about 18 (Table I).

The direct injury produced by stainers is of the same nature as that already described in connexion with the green bug.

A point of great importance for the full appreciation of the losses due to bugs, is that most of the serious damage due to direct bug injury does not appear in the final computation of yield even as stained cotton. Many of the locks are so injured that they are not picked at all, or if picked, are not sent to the ginnery, since they have no separable lint. So far as could be judged, the actual stained lint at the Government Ginnery was principally the result of internal boll disease and bacterial boll disease.

PREVALENCE OF DIRECT INJURY AND INTERNAL BOLL DISEASE IN 1917-18.

The examination of parcels of green bolls from various districts enables a statistical comparison (Table I) to be made of the amount of injury connected with different types and stages of bug infestation. The result is shown graphically in Plate 1. The samples in each case were made up of sound green bolls 20-30 mm. in diameter, taken at random from the fields. The figures in the first section of the table illustrate the conditions brought about in St. Vincent and Batawia by bugs other than stainers, while in the second section the Bequia and Montserrat figures represent very closely the conditions which have prevailed in St. Vincent at corresponding seasons in past years. All except the second lot of Montserrat figures represent lock by lock examinations, in which the microscope was used on all damaged material; the second Montserrat figures were obtained by inspection without the microscope, a method which with experience is reasonably accurate. The records were made in the form shown in the section relating to the bagging experiments.

It will be seen that the proportion of infection and consequent internal boll disease was much less in the samples of bush bug infestation examined than in the case of stainer infestations. The reason for the difference is not clear, but is probably related to the fact that many of the green bugs come in from other plants, and, as seen in those invading the Botanic Station plot, may be free from infection.

TABLE I. PERCENTAGE OF INJURY AND INFECTION IN GREEN BOLLS.

		Date.	Locks.	With clean lint.	Unpunctured.	Direct injury, complete.	Also infected.	Direct injury, partial.	Also infected.	Infection only, complete.	Infection only, partial.	Total of infections.	
				P	er	ce	nt	. :	—				
NO STAINERS.	Expt. Station.	5·12	176	87	*81*			7		1	5	*6*	Bugs numerous on adjacent plants.
	Botanic Station.	28·11	121	54	*46*	26	*2**	19				*2*	Nezaras collected daily in fair numbers.
	Belair.	5·12	96	57	*43*	10		20		10	2	*12*	Bush bugs; fairly abundant.
	Batawia.	8·12	156	68	*67*	8	*1*	18		3	3	*7*	Edessa and Leptoglossus only.
	Peter's Hope.	3·12	88	53	*39*	9	*3*	28		3	4	*10*	Bush bugs; apparently going off.
	Mt. Wynne	3·12	68	81	*73*	2		13	*2*	4		*6*	Bush bugs; apparently going off.
	Sion Hill.	7·12	18	55	*55*	17		11		17		*17*	Bush bugs; abundant.
STAINERS.	Sion Hill.	7·12	52	13	*12*	13		19		52	2	*54*	Stainer-infested field.
	Bequia.	8·12	164	42	*31*	18	*1*	15		20	6	*27*	Stainers breeding up.
	Montserrat	25·1	64	17	*11*	67	*39*	*6*		9		*48*	End of the season; full infestation.
	Montserrat	25·1	126	13	?	65	*16*	11	*6*	11		*33*	End of the season; full infestation.

*Bacterial.

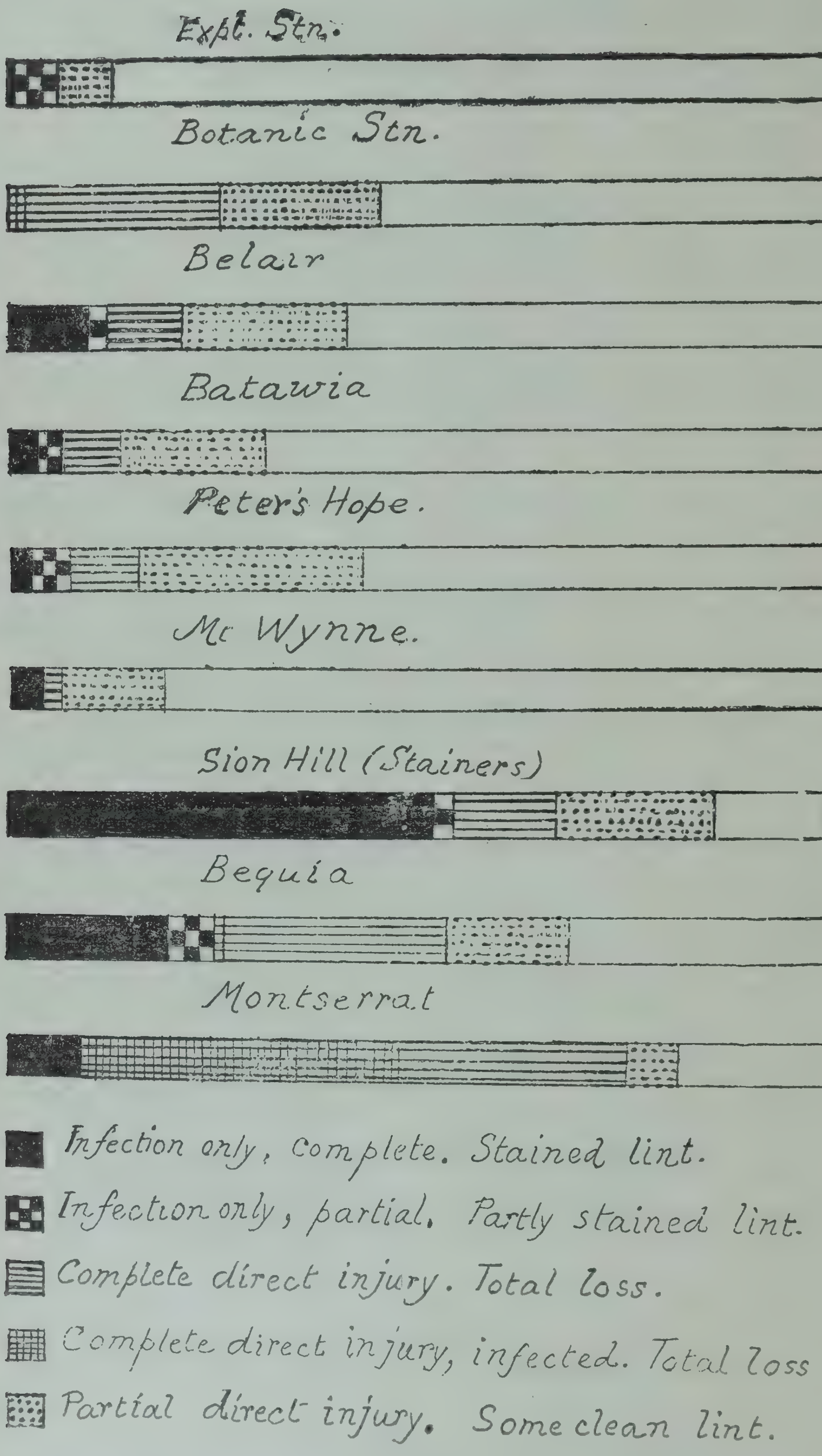

PLATE 1.

Proportion of locks with bug injury and internal boll disease.

The following notes supplement the particulars already incidentally given with regard to the localities referred to in Tables I and III.

EXPERIMENT STATION, St. Vincent: See page 3.

BOTANIC STATION, St. Vincent: The plot already mentioned as free from infection was situated in the Botanic Gardens and was the only cotton grown there, though there were estate fields at no great distance. The area was roughly one-fourteenth of an acre. No bugs other than Nezara were seen on it, and the invasion with this species covered the period of most abundant boll-development, commencing with a few adults about the middle of October. Between October 30 and November 23, i.e. in twenty-five days, 1,027 bugs, mostly adults, were obtained in collections made almost daily. After the latter date few were seen. The yield of clean seed-cotton was 58 lb., and of marketable 'stains' 8 oz.; about 3 oz. more was discarded. This bears out the conclusion already stated that the heavy losses which may occur as a result of direct injury, apart from internal boll disease, are not indicated in the return of stained lint. In the present case the proportion of stains, about 1 per cent., was exceedingly small for St. Vincent, although the Agricultural Superintendent, Mr. W. N. Sands, who has supplied the figures, estimates that the loss due to bugs was 'certainly not less than 25 per cent.' In this estimate are included (a) bolls shed, (b) bolls remaining on the plants undeveloped and not opening, (c) bolls fairly well developed but opening prematurely or partially, and, as in estate practice, passed over by the pickers. The figures obtained by the writer as recorded in Table I, show that at the given date the loss in class (c) alone was 26 per cent. of completely damaged and 19 per cent. of partly damaged locks. The heavy proportion of complete injury is probably to be accounted for by the fact that the bugs were mostly adults.

BELAIR, St. Vincent: These bolls were from peasants' holdings.

BATAWIA: See page 3.

PETER'S HOPE AND MOUNT WYNNE, St. Vincent: These adjoining estates are situated on the Leeward Coast, with bush land and forest behind them. No other crop attractive to bugs had been grown, but there were numerous leguminous plants (Crotalarias, Cassias, etc.) on roadside banks and waste places, and *Cleome viscosa* was a common weed.

When visited on November 9, both Nezara and Edessa had been abundant for several weeks. Very large numbers of young bolls had been shed or were dried up on the plants. This type of loss under the very favourable conditions which had prevailed could only be attributed to bug injury, a conclusion which was confirmed by the condition of such of the shed bolls as were examined. There was also considerable evidence of injury to the bolls which were continuing to develop. The infestation had

reached or passed its highest point, and owing to the measures adopted or to natural control, or both, the conditions greatly improved from this time.

SION HILL, St. Vincent: The first entry under the name of this estate relates to a small field in which bush bugs were plentiful, the second to a field which contained one of the two local infestations of stainers previously referred to. The figures are remarkable for the high proportion of internal boll disease found.

BEQUIA. The bolls recorded were from Spring estate, on which cultivation is very diversified, and includes cowpeas and pigeon peas. Very few leguminous weeds were in fruit when this estate was visited in early November; *Cleome viscosa*, the favourite host-plant for the early stages of Nezara, is rare.

Regarding the final position in the island of Bequia in general, Mr. Sands reports that when he visited the island in mid-January to begin the destruction of silk-cotton and mahoe trees, an inspection of the cotton fields revealed stainers throughout, and all the bolls badly diseased. Cotton is the chief money crop on the island, but he found the peasants afraid to plant it again owing to the record of failure in recent years being continued in a season when climatic conditions were highly favourable. It is hoped to restore confidence before the planting season arrives in view of the better prospects afforded by the measures now taken for the control of stainers.

MONTSERRAT. Stainer infestation in this island followed its usual course. The bolls reported on were obtained from plants about to be pulled up at the end of the season.

NEVIS. Heavy boll-shedding was reported from Nevis in January, and was locally attributed to dry weather. Examination of a parcel of the shed bolls showed that all were heavily infested in practically every lock with the fungi of internal boll disease. The infection of a number of ripe locks forwarded at the same time is recorded in Table III. There were large numbers of stainers in all cotton fields.

VIRGIN ISLANDS. The bolls from Tortola, Virgin Islands, infested as recorded in Table III, were obtained from plots at the Experiment Station on which no cotton stainers had been observed. The presence or absence of other bugs was not recorded.

DISTRIBUTION OF THE FUNGI OF INTERNAL BOLL DISEASE.

Before proceeding to the experimental evidence regarding the transmission of infection by bugs, it is desirable to give the results of the observations made as to (a) the presence of the specific fungi in the fruits of plants other than cotton, and (b) their distribution in cotton bolls at various times and places under various conditions of bug infestation.

As announced in a note appended to the previous paper (loc. cit., p. 273), Harland had noticed early in 1917 affections of

tomatoes and cowpeas at the St. Vincent Experiment Station, which were found on examination by the writer to be due to infections with these fungi. Previous search in the fruits of silk-cotton and mahoe had been without definite result, but the indication given by Harland's observation has led to the finding of one or more of the four species of internal boll disease fungi in the seeds of some twenty species of plants, as follows :—

TABLE II. HOST PLANTS OF THE FUNGI OF INTERNAL BOLL DISEASE.

LEGUMINOSAE.	A.	B.	C.	D.
Vigna catjang, V. unguiculata (Cowpea, Rounceval, Black-eye).	+			+
Dolichos Lablab (Bonavist).				+
Phaseolus lunatus, P. vulgaris (Lima, French bean).				+
Canavalia gladiata (Sword bean).				+
Crotalaria juncea (Sunn hemp).				+
Crotalaria retusa.				+
Tephrosia spp.				+
Indigofera spp.				+
Cassia spp. (herbaceous).				+
MALVACEAE.				
Gossypium spp. (Annual and perennial cottons)	+	+	+	+
EUPHORBIACEAE.				
Ricinus communis (Castor oil).				+
Jatropha urens.				+
SOLANACEAE.				
Lycopersicum esculentum (Tomato).	+	+		+
CUCURBITACEAE.				
Momordica Charantia (Coolie pepper).				+
ASCLEPIADACEAE.				
Asclepias curassavica.				+
RUTACEAE.				
Citrus sinensis (Sweet orange).				+

This table may also be taken as representing the distribution of the fungi at the Experiment Station, St. Vincent, in November-December 1917, since the records, with the exception of *Jatropha urens* (collected in Bequia) and *Citrus sinensis*, were made or repeated there.

The infection that far outweighed the rest in mass was that of Species D on leguminous plants. And it was on these that Nezara, the bug principally concerned in the infection of the cotton, was mainly feeding. Leptoglossus was breeding on bonavist, tomato, and occasionally on cotton.

Boll infections with A, B, and C occurred, but were extremely rare ; practically all were due to Species D. In the tomato, A and B, more particularly A, were fairly common, and A was found occasionally in the Vignas.

The information so far collected as to the relative abundance of the four fungus species in cotton bolls at various times, places, and seasons is summarized in Table III.

The actual figures are given with reserve, since they are based on very unequal amounts of material examined. Taken broadly, they give a correct idea of the relative proportions of the different species occurring, but the entry of 100 per cent. for one species, for example, does not exclude the probability that occasional infections with other species could have been found by extended search.

TABLE III. RELATIVE DISTRIBUTION OF FUNGUS SPECIES IN BOLL INFECTIONS.

Date.	Locality.	Dysdercus.	Nezara.	Leptoglossus.	Per cent. A.	B.	C.	D.
1916 Jan.	Exp. Station, St. Vincent.	out of control	present	not recorded	100	–	–	–
Oct	,, ,,	kept down	,,	,,	–	–	–	100
,,	Georgetown St. Vincent.	breeding up	not recorded	,,	100	–	–	–
1917 Jan.	Exp. Station, St. Vincent.	out of control	present	,,	100	–	–	–
,,	Grove, Montserrat.	,, ,,	not abundant	,,	–	–	100	–
Dec.	Expt Station, St. Vincent.	absent	common	fairly common	1	½	½	98
,,	Belair, St. Vincent	,,	abundant	not recorded	–	–	–	100
,,	Diamond, St. Vincent	,,	,,	,,	–	–	–	100
,,	Peter's Hope, St. Vincent	,,	,,	not seen	–	20	–	80
,,	Sion Hill, St. Vincent	abundant	present	present	72	–	–	28
,,	Bequia.	breeding up	fairly common	fairly common	74	–	23	3
,,	Batawia.	absent	absent	common	50	–	–	50
1918 Jan.	Grove, Montserrat.	out of control	not abundant	not recorded	–	4	92	4
Jan.	Nevis.	abundant	not recorded	,,	5	85	5	5
Feb.	Exp. Station, Tortola.	not seen	,,	,,	–	95	–	5

All four species have now been found in St. Vincent, Montserrat, and Nevis. Certain general statements may be made on the strength of this table: (a) that heavy infestation with stainers has always led to the predominance of Species A in St. Vincent, and Species C in Montserrat; (b) that in St. Vincent green bug infestation leads to the predominance of Species D. The latter fact was evidently correlated, in 1917, with the abundance of Species D in the fruits of leguminous plants, on which, for preference, the green bug feeds. In Bequia, where few leguminous plants were in fruit at the time, there was a notable scarcity of Species D, although Nezara and Leptoglossus were fairly common. It appears certain that there must be a plant or plants, frequented by stainers, which, if it does not serve as a persistent reservoir, as in the case of leguminous plants and Species D, at any rate carries over Species A and C in St. Vincent and Montserrat, respectively. Species A has been found sparingly in the cultivated Vignas and rather frequently in the tomato, but neither host seems adequate for the purpose; Species C has actually been found only in cotton, but in one instance (Experiment E) was transferred to cotton from tomato. St. Vincent no longer affords the requisite conditions for the search, but it is hoped to make some observations in Montserrat during the present season.

The evidence with regard to Leptoglossus is somewhat scanty, but the case of Batawia suggests the tentative inference that it carries both A and D. Two infections with Species A were obtained in cotton bolls to which this insect was transferred from tomato (Experiment E).

The pea chink, Edessa, has been left out of account, although it was present in more or less abundance in each place, because of the uniformly negative results of the attempts made to connect it with infection. It is recognized as possible that this attitude may have to be modified when fuller information is available.

At one stage of the investigations it was thought that Nezara might act as a bridging species in the sense of carrying over infection from other plants to cotton in the early part of the season, to be distributed by stainers as they became common. The present trend of the evidence is away from this conception, since it indicates a change in the prevailing species of fungus as stainers assume predominance in the fields. The full facts of the story are obviously not yet in our hands.

TRANSMISSION OF INTERNAL BOLL DISEASE BY BUGS OTHER THAN STAINERS.

Reference to the summary of the bagging experiments will show that the results demonstrate quite clearly that the punctures of the green bug and the two tomato bugs serve as channels for infection with internal boll disease, as was previously demonstrated with regard to the cotton stainer. In the case of the green bug (II, B and C) there was an infection of every possible boll (two had undeveloped contents), and of almost every lock,

in twenty-one bolls on which bugs from infected plants were confined. Leptoglossus, from various plants which may or may not have been infected, caused two bolls to be infected out of a possible ten. Phthia, from tomato, one infection out of three. In the twenty bolls (II A) bagged with Edessa, which may in this connexion be regarded as controls, there was no infection whatever. No single instance has been met with, in the investigations so far carried out, to show that natural infection with internal boll disease can arise in any other way than through a bug puncture.

The dependence of infections on bug punctures being accepted, it remained to be shown whether the infecting fungus exists on the surface of the boll and merely takes advantage of the opening afforded, or is actually carried by the bug itself.

The evidence from the experiments appears to the writer decisive that the bug is the carrier of infection. In Experiments B and C, of the bolls enclosed with green bugs from leguminous plants infected with Species D, eighteen out of a possible nineteen became infected with that fungus; of five bolls severely injured by green bugs from plants known to be free from infection and of twenty bolls more or less punctured by Edessa, none was infected. In Experiments D and E with Leptoglossus and Phthia, of eight bolls actually punctured, seven heavily, infections occurred in three cases, two with bugs from tomato. One of the latter was with Species A, which is fairly frequent on tomato; one with Species C, the alternative hosts of which are not known. No infection occurred with the species, D, which had so heavily infected the bolls on the same plants bagged with Nezara. Two bolls out of four swabbed with corrosive sublimate solution became infected.

These considerations have reference to fungoid infections only. In the case of bacteria the possibility of chance infection of punctures is left much more open by the evidence so far obtained. The number of bacterial infestations observed this season was very small compared with the corresponding period last year, which supports the conclusion previously reached that they are correlated with wet weather. Cultures made from fungus-infected bolls show that various bacteria may be inconspicuously present in many of them, but only those cases have so far been taken into account in which the bacteria, presumably specific, are sufficiently developed to be the sole cause of, or to take an obvious part in, the staining of the lint. The bacterial phase of the disease requires to be made the subject of separate investigation. Enough has been done to show that several species occur, of which two are usually prominent.

With a view to the elucidation of the conveyance of infection, several days were spent in the careful examination of living and freshly killed bugs for evidence of the presence of the specific fungi. Numerous fungus spores and conidia were found adhering externally, and some were seen in the contents of the alimentary canal. None of these was recognizable as belonging to the species sought, nor was any growth of the required species obtained by transferring parts of the body or its contents to appropriate nutrient media.

SUMMARY OF THE BAGGING EXPERIMENTS.

Method.—The flowers from which the bolls used were derived were enclosed early on the day of opening in numbered cambric bags about $5\frac{1}{2}$ by $4\frac{1}{2}$ inches, confined around the stem with brass wire. The bugs were obtained singly or in pairs in separate test-tubes closed with a tuft of cotton. At the appropriate time each bag was removed in turn, the bug shaken into it without handling, and the bag again replaced. At the end of the period of exposure the bag and its contents were removed by clipping the stem below the wire, and kept together until the examination came to be made.

The first series was of a preliminary nature, and served to show the feasibility of the method. In this series nine bagged bolls were left without bugs, to serve as controls, and remained unpunctured. A further fifteen bolls enclosed with Edessa were also unpunctured. Since seventeen out of twenty-three unbagged bolls collected from the plot at the same time were more or less punctured, the results were regarded as showing that the bags were an efficient protection against outside bugs. Further experience fully confirmed this conclusion.

SERIES I.

Bolls on hybrid cottons of perennial type, bagged from flower stage. Bugs enclosed November 1-6. Examined about ten days later.

EXPERIMENT A. NEZARA.

Ten bolls with *Nezara viridula* of unrecorded origin.

No.	Bugs.	Results.	Infected.
1	1, dead	Unpunctured.	
2	1, alive	+ 118 punctures ; infected all over. ...	D
7	1, alive	About 10 punctures, one infected and stained patch, rest water-soaked.	D
8	1, alive 1, dead	About 20 punctures, no infection or staining, patches water-soaked.	
9	2, alive	Two groups of punctures, no infection or staiing, water-soaked.	–
10	1, dead	Unpunctured.	–
			–

Nos. 3, 5, 6 : boll not recovered ; 4 : bug missing.

EXPERIMENT B.

Ten bolls swabbed with corrosive sublimate solution, 1 in 500. Nos. 1-5 with Nezara, one missing.

No.	Bugs.	Results.	Infected.
1	1, dead	Heavily punctured, proliferated, and infected.	D
2	1, dead	Twenty-four punctures, with infection in all 3 locks; not severe.	D
3	1, alive	Rather heavily punctured, including several seeds. Lint not visibly affected. ...	–
4	1, alive	Punctured all over. Seeds browned and pasty; lint agglutinated; ruined. ...	–

Nos. 6-10 with Edessa, two of which were alive: no punctures penetrating to lint.

EXPERIMENT C.

Ten bolls with *Edessa meditabunda* from infected Sunn hemp.

Nos. 1-10 recovered, bugs dead at close of experiment, but observed to remain alive for some days: no punctures penetrating to lint.

CONTROLS.

Nine bolls bagged without bugs: all unpunctured.

SERIES II.

Bolls on a row of vigorous Sea Island plants. Flowers bagged November 5-8.

EXPERIMENT A. EDESSA.

Twenty bolls with *Edessa meditabunda* from infected bonavist, Tephrosia, and cowpea; bugs enclosed November 16 (eight to ten days from open flower) two in each bag, except No. 20, which had eight; bolls examined November 26-27 (ten days later). No infection occurred.

No.	Diameter in mm.	Condition of bugs.	Results.
1	15	brood	Three punctures in one lock; lint unaffected.
2	15	dead	A few punctures in each lock; one small yellow patch on surface of lint.
3	28	dead	No punctures visible.
4	23	brood	No punctures visible.
5	25	1 alive, brood	Two locks with several punctures near tip proliferated, local superficial staining; one has also 2 punctures at base with local stain. Third punctured near tip, no effect on lint.
6	22	1 alive, brood	About 6 punctures per lock, upper half; well defined local patches (about 3 mm. in diameter) of orange-yellow surface stain.
7	21	1 alive, brood	All locks rather heavily punctured and proliferated, upper half; several local patches of deep orange-yellow surface stain.
8	20	dead	A few punctures; lint unaffected.
9	20	1 alive, eggs	One puncture visible; lint unaffected.
10	27	dead	No punctures visible.
11	27	dead	,, ,, ,,
12	20	dead	,, ,, ,,
13	23	dead	,, ,, ,,
14	27	1 alive, brood	Two locks with about 8 punctures each: lint unaffected. Third lock with about 15 punctures of which a group near the tip is proliferated and has a surface patch of stain beneath it.
15	23	1 alive, brood	Three locks with about 10 punctures each. In two cases, near tip, a local surface stain is associated with a puncture.
16	27	dead	No punctures visible.
17	25	dead	,, ,, ,,
18	25	dead	,, ,, ,,
19	23	dead	Four punctures visible; one causing a very small surface stain.
20	31	7 dead 1 alive.	Three locks with about 12 punctures each; no proliferation; one puncture only, at tip, has caused a slight surface stain of small area. Fourth lock with more than 30 punctures of which 2 or 3 of a large group have caused a slight proliferation and a narrow patch of yellow surface stain.

NOTE: No. 20 included here for convenience, came in Experiment C; bugs introduced 20 days from flowering, bolls examined 9 days later; several of the bugs were alive after 5 days.

EXPERIMENT B: NEZARA ON YOUNG BOLLS.

Twenty bolls with *Nezara viridula,* from infected bonavist and indigo, and from an uninfected cotton plot. Flowers bagged November 5-8: bugs introduced, two to a boll. November 16 and 17; bolls examined ten days later.

No.	Mm.	Shed.	Bugs alive.	Food-plant.	Results.	Infected.
1	10	s	2	bean	Heavily infested and lint completely stained.	D
2	10	s	0	,,	Heavily punctured, proliferated, and stained, injury partly direct, partly due to infection.	Ba
3	13	s	2	,,	Heavily punctured, proliferated, and stained; fully infested.	D
4	15	s	0	,,	Heavily punctured and proliferated: contents undeveloped.	–
5	10	s	0	,,	Punctured; only three seeds developed (one lock); locally infected and stained.	D
6	8	s	0	,,	Heavily punctured and seeds only partly developed; completely infested and stained.	D
7	12	s	2	,,	Heavily punctured and proliferated; completely infested and stained.	D
8	8	s	0	,,	Punctured, completely infested and stained	D
9	7	s	0	,,	Heavily punctured; only two seeds developed, infested and stained.	D
10	22	–	1	,,	Very heavily proliferated; completely infested and stained.	D
11	5	s	0	ind.	Heavily proliferated; infested and stained.	D
12	13	s	0	,,	Very heavily punctured and proliferated; completely infested and stained.	D
13	5	s	0	,,	Heavily proliferated; contents undeveloped.	–
14	9	s	0	,,	Fully infested and stained.	D
15	18	s	1	,,	Heavily punctured and proliferated; completely infested and stained.	D
16	20	–	?	cot.	Very heavily proliferated in all locks; very slight staining in two locks only.	–
17	11	s	0	,,	Heavily punctured and proliferated; no staining.	–
18	12	s	1	,,	Very heavily punctured and proliferated; slight staining.	–
19	16	s	1	,,	Heavily punctured and proliferated; very slight staining.	–
20	17	s	1	,,	Punctured and proliferated; bright-yellow staining in contact with 4 killed seeds: rest clean.	–

EXPERIMENT C: NEZARA ON FULL-GROWN BOLLS.

Six bolls with *Nezara viridula* from infected bonavist bean, six with same species from castor oil plants at Botanic Station. Flowers bagged November 5-8; bugs introduced, two to a boll, November 28; bolls examined nine days later. The bolls had estimated diameters of 22-27 mm. when bugs were introduced. No boll was shed in this experiment. The bugs from castor oil, although five (on three bolls) were alive at the end of the experiment, refused to feed and the bolls remained unpunctured. The table refers to the bugs from bonavist.

No.	Mm.	Bugs alive.	Lock.	Results.	Infected.
1	25	1	a	Many proliferations, one 10×8 mm.; two thirds of lint infested and stained.	D
			b	About 20 punctures in a group; partially infested and stained.	D
			c	Punctured and proliferated all over; completely infested.	D Ba
2	26	2	a	Very heavily punctured and proliferated upper half, which is infested and stained.	D
			b	About 10 punctures; half lint infested and stained.	Ba
			c	Punctured all over; 4 separate infections, which have not coalesced.	D
3	22	0	a	Seven scattered punctures with no effect on lint; one group, infected, involving lint on 3 seeds.	D
			b	Many scattered punctures with no effect on lint: one infection at tip	D
			c	About 15 punctures with negligible effects.	–
4	25	2	a	Three large proliferations, 9 punctures not proliferated; 3 separate infections involving most of lint.	D
			b	Five groups of punctures, one proliferated; 5 separate infections.	D
			c	Heavily punctured and proliferated; fully infested and stained.	D
5	27	2	a	Thickly punctured all over; proliferations very numerous; many scattered infections, one involving half the lint.	D
			b	The same; many scattered small infections.	D
			c	The same; direct injury only, general but slight; a little discoloration of lint in contact with injured seeds	–
6	23	0	a	Unpunctured.	–
			b	Unpunctured.	–
			c	Two groups of punctures, one proliferated; 2 small local infections.	D

EXPERIMENT D: LEPTOGLOSSUS ON YOUNG BOLLS.

Ten bolls with *Leptoglossus balteatus*, from bonavist bean, tomato, and Batawia cotton. Flowers bagged November 5-8. Single bugs enclosed November 16; bolls examined ten days later.

No.	Mm.	Food-plant.	Bug.	Shedding.	Results.	Infected.
1	22	bon.	alive	–	Two locks heavily punctured and proliferated, two so affected at tip only. Lint of two punctured and proliferated seeds slightly discoloured yellow. One lock has punctured, slightly discoloured seeds with lint water soaked and adhering but not stained. No infection.	–
2	23	bon.	alive	–	No visible puncture.	
3	22	tom.	dead	–	One puncture; no effect.	–
4	20	tom.	dead	–	No visible puncture.	–
5	15	tom.	alive	s	Punctured in two locks with small and numerous proliferations. Both locks infected and stained, one completely.	A
6	27	cot.	dead	–	No visible puncture.	–
7	16	cot.	dead	s	Heavily punctured and proliferated. Several seeds killed, lint water-soaked and adhering, not stained, no infection.	–
8	24	cot.	alive	–	About 20 punctures, 5 seeds with swellings and brown patches, over which the lint is yellow. No staining on rest of lint. No infection.	–
9	18	cot.	dead	s	Injury similar to last but more severe. All seeds more or less injured and probably most or all killed; would give a completely ruined boll, with lint reduced to a discoloured film. No infection.	–
10	25	cot.	alive	–	All lint of 2 locks reduced by direct injury to a yellowish brown film, also infected. Third lock as (8) above.	A

EXPERIMENT E: PHTHIA ON YOUNG BOLLS.

Three bolls with *Phthia picta* from tomato. Conditions as in D. None shed.

No.	Mm.	Bug.	Results.	Infected.
1	20	alive	Two locks heavily proliferated, completely infested and stained. One lock with local yellow staining without infection.	C
2	28	dead	No visible puncture.	–
3	28	alive	No visible puncture	–

EXPERIMENT F: STERILE LEPTOGLOSSUS ON FULL-GROWN BOLLS.

Six bolls with Leptoglossus reared from an early stage on uninfected material*. Flowers bagged November 5-8; bugs introduced November 28; bolls examined nine days later. There was no shedding and no infection with internal boll disease.

*Provided by the Entomologist.

No.	Mm.	Bug.	Lock.	Results.
1	23	dead	a	About 20 punctures, 3 proliferated; each seed heavily punctured and lint in contact
			b	stained and somewhat agglutinated. Staining not general but lock spoiled.
			c	One seed punctured and injured as above; only other seed undamaged and lint clean.
2	22	dead		Unpunctured.
3	28	alive	a	At least 20 punctures; a long chain of proliferations on suture line; remaining punctures visible within as dark green spots, some visibly penetrating; damage very small, consisting of negligible small yellow tufts; 2 seeds proliferated but no contact discoloration. Remaining three locks one puncture only; no damage.
4	26	alive	a	Group of 6 unproliferated punctures with no damage; 1 proliferated puncture causing water-soaking without discoloration.
			b	One group of proliferated punctures, 2 seeds as in No. 1, rest of lint clean.
			c	Fourteen punctures, of which half are proliferated; injury as in No. 1, but discoloration slight.
5	29	dead	a	One puncture, with a small yellow spot on surface of lint.
			b	Heavily punctured; 4 proliferations; one deeply stained small patch over a discoloured seed.
			c.d	Unpunctured.
6	25	alive		Two locks with about 10 punctures each slightly proliferated; effect negligible.

SUMMARY.

The present paper reports on the continuation of the studies of internal boll disease and its connexion with plant bugs recorded in two previous papers in this Journal, with especial reference to conditions in St. Vincent in 1917.

The success of the control measures adopted against the cotton stainer in that island was found to have reduced the prevalence of the disease to negligible proportions over large areas.

Severe infestations with the green bug and the pea chink occurred in some localities, and the resulting damage to cotton bolls afforded the principal subject of study.

Close attention was given to the direct effect of bug punctures on the bolls, and it was found, in regard to the green bug especially, that the resulting injury to the developing seeds prevents or stops the development of the lint, causes the shedding or drying up of young bolls, and is in both ways the source of heavy losses. Punctures made by cotton stainers and the leaf-footed bug have similar effects.

The losses brought about by direct injury are for the most part complete, and are additional to those caused by the staining of developed lint due to internal boll disease. The amount of injury of the latter nature was found to be notably less in the case of green bug than of stainer infestation.

The direct injury resulting from infestation with the pea chink was small in amount, and consisted of stained spots on the surface of the lint, occurring immediately below some of the small proportion of punctures which appeared to penetrate the wall of the boll. No injury to the seeds was observed in connexion with this bug, and no case of infection with internal boll disease.

Table I and Plate 1 afford information as to the prevalence of direct injury and internal boll disease in the localities from which material was obtained for examination.

Table II records the presence of the fungi of internal boll disease in the fruits of local plants belonging to seven orders and fifteen genera.

Table III gives the relative distribution of the same fungi in cotton bolls in numerous localities at various times.

A series of experiments is recorded illustrating the effect of confining bugs from known food-plants on previously protected bolls of known age. Evidence was obtained that the punctures of the green bug readily bring about infection with the fungi of internal boll disease, but only when the bugs are transferred from infected plants. No infection was produced even in the latter case by the pea chink.

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NOTES ON CERTAIN PLANT BUGS CONNECTED WITH COTTON IN ST. VINCENT.

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INTRODUCTION.

The following notes are based mainly on some observations made by the writer during a period of five weeks in November and December 1917, on certain plant bugs, known to be, or suspected of being, connected with cotton in St. Vincent. Some of these bugs, such as the cotton stainer (*Dysdercus delauneyi*), the 'bush bugs' (*Nezara viridula* and *Edessa meditabunda*), and the leaf-footed tomato bug (*Leptoglossus balteatus*) are now known to damage cotton bolls to a greater or less degree by their punctures. The nature and extent of the injuries caused by these bugs have been fully discussed by W. Nowell* in an earlier paper, and again in another part of the present number (pp. 1-12), and no further reference is needed here. Other species, such as *Phthia picta*, *Acanthocerus lobatus*, *Piezodorus guildingi*, etc., while they have not been definitely connected with cotton, are known to feed on some of the host plants of the fungi of internal boll diseases other than cotton, and should therefore be regarded with suspicion, pending further investigations.

The field observations were supplemented by investigations connected with the habits and life-histories of some of the above-mentioned bugs under laboratory conditions. Some of these experiments, relating to bugs not known to occur in Barbados, were given up on leaving St. Vincent, but in the case of species known to be common to both islands the life-cycle studies are being continued here as far as possible. It is hoped to publish the results of this work in a separate paper at a later date. In the present paper the writer proposes to give notes mainly on the cotton stainer and on the green bug, which were the two most important species observed in St. Vincent. The other species of plant bugs will only be referred to briefly, pending further study.

THE COTTON STAINER (*Dysdercus delauneyi*, Leth.).

ST. VINCENT. The cotton stainer has been an important pest of cotton in St. Vincent for many years, but was not regarded as really serious until a succession of bad stainer years coinciding with exceptionally wet weather was speedily reducing the cotton industry in that island to the position where the growing of clean cotton was becoming an impossibility. The real danger from this pest became evident as the result of some recent discoveries. The investigations of Nowell (*loc. cit.*) conclusively demonstrated (1) that this bug is an agent in the infection of green unopened bolls with diseases of fungus and bacterial origin, which subse-

*Nowell, W., 'Internal Disease of Cotton Bolls in the West Indies': *West Indian Bulletin*, Vol. XVI, No. 3, pp. 203-35.

quently produce a staining and rotting of the lint ; and (2) that in some instances it causes direct injury to the seeds of unopened bolls resulting in more or less damage to the contents of the bolls. In both cases the damage is the result of punctures made by the bug. W. N. Sands,* as the result of his field observations on the cotton stainer in its relation to its alternative food-plants, showed that this pest was able to tide over the period between the end of one cotton season and the beginning of another, by breeding on the pods of such trees as the silk-cotton (*Eriodendron anfractuosum*) and the mahoe or John Bull (*Thespesia populnea*). It was therefore decided to eradicate these food-plants throughout the island, and this campaign was carried out under the provisions of the Cotton Stainer Ordinance, St. Vincent (1916). At the same time large numbers of stainers were destroyed by attracting them to heaps of cotton seed, and then killing them by the application of a gasolene torch.

Speaking generally, it may be said that the results of the eradication campaign appear to have entirely justified the drastic measures taken during the previous season. The writer was in St. Vincent at a time of the year when in former years the cotton stainer, with no natural enemies to check it, used to be breeding up on cotton preparatory to getting entirely out of control.

On this occasion, however, apart from two small local outbreaks of known origin and extent, the cotton stainer was on all sides either completely absent, or else an entirely negligible factor both in relation to cotton and to its alternate host-plants.

The experiences of the cotton season of 1917-18 have shown in two instances how easy it is for the cotton stainer to breed up unobserved on a few trees, or on cotton seed refuse, and then migrate to cotton fields. Recent reports from St. Vincent all tend to show that, on the whole, there has been an excellent cotton crop, and that confidence has been restored.

Before passing on to measures for the control of the cotton stainer, it may be of interest to refer to the position of this insect as observed by the writer in two of the neighbouring cotton-growing islands. The islands of Bequia and Batawia afforded a striking contrast in the stainer situation at the time the observations were made in November 1917 by the Mycologist and Entomologist.

BEQUIA. The cotton stainer was known to be present in Bequia, but the exact status of the pest had never been definitely investigated, and its alternate host-plants were still uncontrolled at the time of our visit. Observations showed that the cotton stainer was breeding freely on the cotton, and that other plant bugs, such as Nezara, Edessa, and Leptoglossus were present. The cotton crop was being seriously damaged by internal boll diseases. The presence of silk-cotton and John Bull trees on the island indicated the sources of the stainer infestation. As a result of the report of our visit, the Agricultural Superinten-

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*Sands, W. N. 'Observations on the Cotton Stainer in St. Vincent'. *West Indian Bulletin*, Vol. XVI, No. 3, pp. 235-55.

dent of St. Vincent took in hand the elimination of the wild food-plants of the cotton stainer from the island of Bequia, and this work was carried out during the early part of the year 1918. The success of these measures will mean everything to the local cotton growers, who from all accounts had almost decided to give up cotton cultivation.

BATAWIA. The stainer situation in the small island of Batawia may be briefly sketched as follows. Mr. Sands visited the island in August 1916 and found the cotton stainer breeding abundantly on the wild ochro (*Malachra capitata*). He strongly urged the immediate eradication of this plant throughout the island. He accompanied the Mycologist and the Entomologist to Batawia in November 1917. and an inspection of the area under cotton was made. There were no cotton stainers to be seen anywhere, nor was Nezara in evidence. Edessa was swarming on pigeon pea growing among the cotton, while Leptoglossus was fairly common on cotton, and was evidently responsible for some injury. The nature and amount of injury done by these bugs are given by Nowell (p. 3). The scarcity of the stainer could be mainly attributed to the absence of its alternate food-plant, the wild ochro, which had been eradicated in the previous year. As far as we could learn, there were no other wild food-plants of the cotton stainer on the island.

The cotton stainer situation in the three islands of St. Vincent, Batawia, and Bequia afforded an interesting comparison at the end of 1917. In the first two islands we see a great reduction in the numbers of the stainer resulting from the control or eradication of its alernate food-plants, while in Bequia the pest had been left quite untouched, and had practically ruined the cotton crop.

THE CONTROL OF THE COTTON STAINER.

The experiences of the 1917-18 cotton season in St. Vincent have demonstrated that the tentative measures taken to control the cotton stainer have met with a far greater success than was even thought possible. It was realized, however, that the blockade must be drawn still tighter, and that certain modifications and additions in the provisions of the Cotton Stainer Ordinance would be necessary. It is understood that these have been made, and will be in working order during the cotton season which is now beginning. The confidence of the local cotton growers has been entirely restored, and they are now fully alive to the fact that the cotton stainer must be kept in check by artificial measures, since there appear to be no natural enemies of any importance.

It is fortunate that, so far as is known at present, the stainer feeds only on plants belonging to the Natural Orders Malvaceae and Sterculiaceae (Sands, *loc. cit.*, pp. 245-50). the last named Order having only one representative. the Mahoe Cochon or Stave Wood (*Sterculia caribaea*). The extent and distribution of these plants are no doubt definitely known by this time, and none of them are of any economic importance as compared with cotton. It is therefore simply a question of entirely eradicating these alternate food-plants where practicable, and controlling the

fruiting of all such plants as it is impracticable to destroy. Where there is the slightest doubt, however, of the ability to control such plants, it is strongly urged that they be entirely eliminated, as otherwise they will only be a constant menace to the cotton crop while stainers remain in the island. It is realized that their destruction has already been carried out in the great majority of cases, and that a periodical survey of the island is being maintained to deal with any new growths that may spring up from time to time. It is hardly necessary to point out how essential it is that such an inspection be kept up in the future, and be thoroughly and systematically carried out.

There then remains the problem of the control of the cotton stainer in its relation to the cotton crop, not only while this crop is growing in the field, but after it is picked. The stainer has time and again demonstrated its ability to breed up as easily on cotton while it is still on the plants as on any cotton refuse which invariably collects in the neighbourhood of cotton ginneries and cotton houses, unless this refuse is systematically destroyed at frequent intervals.

The stainer has now been reduced to the position where it can be dealt with in the field by such measures as hand collecting, and the use of traps composed of cotton seed, seed-cotton, or cotton-seed meal. The use of gasolene torches to kill the stainers attracted by these traps has been found to be effective in St. Vincent. In this connexion clean picking of all bolls during harvesting is of great value in keeping down the numbers of the cotton stainers. Cotton growers should therefore be urged to pick their plants clean of all open bolls, including those with remains of badly damaged seed-cotton. Material of this kind only serves to attract and breed up any young stainers that are in the vicinity of cotton fields.

With regard to the control of cotton stainers in the neighbourhood of ginneries and storehouses, it is recommended that all owners of cotton ginneries and houses should be urged to clean up at frequent intervals all cotton seed, seed cotton, or cotton seed meal refuse near said houses or ginneries. This material could be used as traps for stainers and then treated with applications of a gasolene torch, or else burnt or buried. Such precautions would greatly lessen the chance of young stainers completing their development and then migrating to start a new infestation elsewhere.

There is one other important measure by which the existence of the cotton stainer in St. Vincent can be made still more precarious, and that is, the employment of a close season for cotton. The question of a close season for cotton was suggested by Sands (*loc. cit.*, p. 251) but it was not practicable to employ this measure as a prelude to the cotton season of 1917-18. It has, however, been brought into use for the present season, the month of April having been definitely set apart for this purpose. This means that all old cotton stalks must be pulled up by the end of March, and that no new cotton can be planted before May 1. And since cotton planted early in May will not be fruiting much before July, it follows that if this measure is properly carried out the cotton stainer will be deprived

of cotton plants, on which it can breed, from the end of March until July. In former years the pest was able to breed on its alternate food-plants during this period, and then to migrate to cotton in July or August. The almost entire removal of the wild food-plants of the stainer and the establishment of a close season for cotton ought to deprive the stainer of almost all plants on which it can breed, so far as is known at present, between the end of March and some time in July.

Sands (*loc. cit.*, p. 245) stated that 'in St. Vincent, for a few days when food is scarce, as is the case in certain districts after the old cotton stalks are burnt and the above named trees (i.e. alternate food plants) are not fruiting or near at hand, the stainer in order to sustain life, or complete maturity previous to flight in search of food, is sometimes found feeding, but not breeding, on flowers of the mango (*Mangifera indica*), *Eupatorium odoratum*, black sage (*Cordia cylindrostachys*), and the Horse Radish tree (*Moringa pterygosperma*); on the fruit of Maiden's Blush (*Momordica Charantia*), and on secretious of scale insects.'

The cotton stainer was observed on these flowers and scale insects during the dry months of February, March and April, and was apparently seeking nectar, or honeydew. It was concluded that 'these substances provide the pest with its only means of obtaining the moisture necessary for its existence.'

This is a point that should be taken into consideration in the future, and it would be advisable to keep a lookout for stainers in such feeding places, and control them by collecting or trapping where necessary.

Furthermore, it is not impossible for the cotton stainer to adapt itself to other food-plants outside its former range, and such a possibility should be borne in mind.

Other Plant Bugs Attacking Cotton in St. Vincent.

Previous to the cotton season of 1917-18, the cotton stainer has been so much in evidence as a pest of cotton that very little notice has been taken of any other plant bugs, and any damage that these other species may have done in the past has usually been credited to the stainer. Within recent years, however, the so-called 'bush bugs', namely, the green bug (*Nezara viridula*) and the pea chink (*Edessa meditabunda*) came to be regarded with suspicion. The investigations of Nowell (*loc. cit.*) indicated that the green bug must in future be regarded as a definite pest of cotton. So that when local outbreaks of these bugs occurred during the last cotton season, it was decided that the writer should go to St. Vincent with the object of making observations on these and other plant bugs connected with cotton.

The relegation of the cotton stainer to a position of minor importance allowed the true status of *Nezara viridula* and other species connected with cotton to be estimated with a clearness that would otherwise have been impossible.

The Green Bug (*Nezara viridula*).

DISTRIBUTION AND FOOD-PLANTS. The green bug is common in St. Vincent, and, as is the case with most other plant-feeding

bugs of the family Pentatomidae, has a wide range of food-plants, and shows a marked preference for pod, and capsule-bearing plants, puncturing the seeds while these are young and succulent. Observations made by the writer in St. Vincent tend to show that this bug breeds primarily on a number of the common local weeds, which are included under the general term 'bush', but that it also breeds on many of the leguminous crops, such as various peas and beans. A preliminary list of the food-plants of the green bug is appended, with notes. This list is arranged in groups more or less in a tentative order of preference, and will doubtless require certain additions and modifications in the light of further observations.

Polanisia (Cleome) *viscosa* ('ground dove feeding', or 'dove bush'). A common weed in St. Vincent, and found in many cotton fields. This seems to be a favourite plant for the egg-masses and younger nymphs of Nezara, but with the exception of an occasional egg-laying female, fifth instar nymphs and adults were very rarely seen on it. The long, slender, sticky pods are tightly packed with a large number of small seeds which do not appear to be used very much as food by adult bugs. This is a most undesirable weed to have in cotton fields as it serves as a convenient breeding place for young Nezara, which later transfer to the adjacent cotton or to other plants. It is also not at all easy to keep down when once it has become established in a locality, as it seeds freely, and grows with great rapidity and luxuriance.

Cleome pungens (Stinking miss). Another of the common 'bush' weeds and a favourite breeding plant of Nezara. It is sometimes found round the edges of cotton fields, and is therefore a source of danger to the cotton crop.

Dolichos Lablab (bonavist).
Vigna spp. var. (cowpea, rounceval, black-eye).
Cajanus indicus (pigeon pea).
Phaseolus lunatus (Lima bean).
Phaseolus vulgaris (French bean).
Canavalia gladiata (sword bean).

The green bug commonly breeds on any of the above leguminous crops when these are fruiting.

Arachis hypogaea (ground nut).
Ricinus communis (castor bush).
Nicotiana tabacum (tobacco).
Lycopersicum esculentum (tomato).

The above cultivated plants are fairly frequently used by Nezara as breeding plants.

Gossypium spp. (cotton).

The green bug is sometimes found breeding on cotton, but so far as the writer's personal observations go, this plant is not among the more favoured breeding plants of this bug. The adults, however, seem to feed on it to a moderate extent, mainly on the young and half-grown bolls, their object being to puncture and feed on the seeds while they are still succulent.

Indigofera spp., *Tephrosia* spp., *Cassia* spp., and *Crotalaria* spp.

These comprise a group of plants on which Nezara adults have been fairly frequently observed resting and mating, and occasionally feeding, but only on rare occasions have egg-masses or younger stages been found on these plants. These include some of the common leguminous herbaceous weeds and their related cultivated species.

The green bug has also been seen by the writer on ochro (*Hibiscus esculentus*), on *Kosmos* sp., on *Heliotropium* sp., and on leaves of sweet potato (*Ipomoea Batatas*).

The Relation of Nezara to Its Food-plants.

The question of the relation of Nezara to cotton and its other food-plants in St. Vincent is one which requires further study before anything very definite can be said about the different aspects of the situation. The list of the food-plants of *Nezara viridula* which has been given above shows that this bug is a very general feeder, and that several of its food-plants other than cotton are of economic value. As previously mentioned, Nowell has shown that Nezara is definitely connected with the infection of green unopened cotton bolls with the fungi of internal boll diseases. Again, in another part of this number (p. 13) the same writer gives a list of plants, in the seeds of which he has found some of these same fungi, and it will be seen by comparing Nowell's list with the list of Nezara food-plants given in the present paper, that there are several species of plants which are common to both lists. In other words, several of the species of host-plants of the said fungi are also food-plants of Nezara; some of these are the varieties of peas and beans commonly grown in St. Vincent.

Now it is not an uncommon practice in that island to grow a leguminous crop, say black eye peas, either as a catch crop just before the cotton, or as an inter-crop with the cotton, and until the above discoveries were made there was nothing to suggest that these crops were a source of danger to the cotton, given the presence of Nezara. Repeated observations made under field conditions indicate that the growing of a leguminous crop either as a catch crop or an inter-crop is a practice liable to be injurious to the adjacent cotton crop, in cases where the green bug is prevalent. On the other hand, where no leguminous catch crop or inter-crop is grown, and where the fields are kept free of weeds, it was observed that very few green bugs were attracted to such fields, as none of their favourite food-plants was present.

A striking example of the contrast between these two situations was seen by the writer in the case of two fields of cotton growing on the same estate. Both fields had been planted with the same strain of cotton, and at the time of our visit in November 1917, the plants in both cases were well grown and in bearing. In field A. a fair number of the older bolls had been lost through shedding at an earlier stage, although there had been no spells of wet weather to account for this loss, nor were the plants too crowded. Both of these conditions are often responsible for boll shedding. The remaining older bolls were well developed, and to all external appearances sound. But on

cutting open some of these bolls a fair percentage were found to be punctured and stained, and had evidently been attacked by a fairly heavy infestation of bugs at an earlier stage. At the time of our visit Nezara was present but far from abundant, and could, as a rule, only be found by a careful search within the bracts. There were also some Edessa, mostly on adjacent pigeon pea plants which were not in bearing at that time. (This was before Edessa had been shown to be comparatively harmless.) The younger bolls were sticking on well, and there seemed to be very little staining in them due to bug injury. The field had been kept pretty clear of weeds, and there was very little of the weed *Polanisia viscosa* to be seen, so that it was difficult to account for the earlier heavy infestation of bugs. Then we learnt that a catch crop of black-eye peas had been grown ahead of the cotton earlier in the season. Bugs had evidently bred up on this crop, and with the removal of the pea crop had attacked the cotton. The bugs had become infected from the pea crop, or from outside sources, and had transferred this infection to the cotton.

In field B, the plants had been grown under much the same conditions and were doing well, but this field had been planted later than field A, and for this reason the catch crop had been omitted. Field B was practically clear of weeds, and bugs were very scarce, as there was practically nothing for them to feed on except the cotton. The plants were covered with well developed bolls and there had been very little shedding; an examination of some of the bolls showed that the lint was remarkably free from staining. The only factor to which the comparative absence of staining in this field could be attributed was the absence of a leguminous catch crop. It may be added that there had been no idea of any experiment in the mind of the estate owner who had never considered the question of plant bugs and their connexion with leguminous crops and cotton.

It was stated elsewhere that the growing of a leguminous crop, either as a catch crop before the cotton or as an inter-crop with cotton, is liable to be a source of danger to the cotton crop. This statement requires some modification. The growing of the said catch crop or inter-crop is not a good practice, in that it serves to attract any bugs that are in the neighbourhood, and an entirely new infestation of bugs, Nezara for example, is started in the vicinity of cotton. While the legume crop remains, however, it does not appear likely, as far as observations show at present, that the bugs will desert a favourite food-plant for one less preferred. But as soon as the legume crop is pulled up or turned under, the infesting bugs will presumably go to the growing cotton in preference to starving, unless there are other more favoured food-plants in the immediate neighbourhood. This is not an argument in favour of allowing weeds to grow round the edges of the cotton fields in order to attract bugs from the cotton, as there is always the danger that the bugs, in the absence of natural enemies, will get beyond control. It is then the sudden removal of a legume catch crop or inter-crop, without previously controlling the infesting bugs, that must be considered as a source of danger to the adjacent cotton crop, rather than the actual growing of it in the first place.

It is, however, advisable not to grow a leguminous crop in connexion with cotton, at any rate at the time at which it is usually grown in St. Vincent. If it is considered necessary to grow a legume for green dressing and for the food it produces, such a crop should be planted well ahead of the cotton. It should be employed mainly as a trap-crop, and all infesting bugs should be systematically controlled. The control of these bugs is essential for two reasons: first, because of their menace to the cotton crop which is to follow; and secondly, for the reason that, given the presence of the fungi of internal boll diseases, they are capable of seriously damaging, if not entirely ruining, the whole food crop by puncturing the seeds and infecting them with disease. Instances of such damage have already occurred in St. Vincent.

Clean cultivation in and around cotton fields is recommended as an important factor in the control of the green bug. This means that not only the fields themselves should be kept as free as possible of such plants as the 'dove weed', but that the edges of the fields, and the banks along the roadside should be kept clear of 'bush'. The growing of a grass crop along the banks is recommended, since this will not only serve to reduce weeds, but will be of some value as a forage crop.

On estates where a variety of crops is grown in addition to cotton, the growing of such crops as peas, beans, or ground nuts in the immediate vicinity of cotton should be avoided, as far as possible. In any case, every effort should be made to control the plant bugs, which, in the absence of their parasites, are almost certain to be abundant on such crops. The failure to do this will, in the absence of parasite enemies, probably result in outbreaks of 'bush bugs' similar to those which occurred on some estates during August to October 1917. The main difference between the stainer infestations and those of the 'bush bugs' is that whereas the stainer got more numerous as the cotton season progressed and finally went entirely out of control, the 'bush bugs' increase rapidly, reach their maximum abundance in a comparatively short time, and disappear almost as quickly, only to reappear later perhaps in some other district; and moreover, these outbreaks are as a rule only of local occurrence. This brings us to the question of the seasonal abundance of Nezara.

THE SEASONAL ABUNDANCE OF THE GREEN BUG. The periodic increase and decrease in the numbers of the green bug in St. Vincent seems to be controlled by at least two natural factors, namely the supply of food, and the efficiency of its natural enemies, which, so far as is known at present, consist of at least two species of minute hymenoptera, or wasps, which destroy the egg-masses.

The rather sudden outbreak of 'bush bugs' (Nezara and Edessa) which occurred in a few districts in August and September seems to have caused much apprehension among cotton growers, who thought that they had got rid of the stainer only to be overtaken by a worse fate. It seems probable, however, that the actual numbers of Nezara were somewhat exaggerated, since at that time the pea chink (*Edessa meditabunda*) was not distinguished from its more dangerous contemporary,

the green bug, but both were collected together indiscriminately, and quite rightly too. It seems probable, however, that the pea chink was just as abundant as the green bug, if not more so. Although Edessa is now known to be comparatively harmless, and is considered to be incapable of causing infection of cotton bolls with disease by its punctures, still it is not a desirable insect to have in the neighbourhood of cotton fields.

The outbreak of 'bush bugs' was fortunately of comparatively short duration, and by the end of October the greatest severity of the attack had passed, and the egg-parasites were evidently beginning to catch up on the bugs, but not before the bolls of the first picking had been fairly badly damaged in some localities. Another small local outbreak of Nezara * occurred in one district on the pigeon pea (*Cajanus indicus*), when this plant was bearing during the early part of 1918. This was one of the districts in which the parasites of the green bug have been very scarce during the past season.

It would appear that the egg-parasites of the green bug were somewhat unevenly distributed during the past cotton season in St. Vincent, and it ought to be a comparatively simple matter to regulate the distribution and seasonal abundance of these natural enemies by artificial means, so that a more even general distribution is assured.

It is suggested, then, especially for those estates where a variety of crops is grown and outbreaks of Nezara are likely to occur, that a small observation crop of some favourite food plant of the green bug, say, black-eye peas, be planted as soon as the first rains come after the dry season. This would serve to attract bugs at the beginning of the season, and would be in the nature of a trap-crop, as mentioned elsewhere, except that a more careful watch could be kept for egg-parasites. The total absence of parasites could be remedied by a consignment from localities which are well supplied, while small colonies might be increased by breeding.

EGG-PARASITES. Experiments with these parasites indicate that they breed very freely with an abundant supply of eggs, but their increase in numbers is naturally limited by the number of eggs of Nezara. One of the species observed is also a parasite of the eggs of Edessa, and possibly of the eggs of other plant bugs as well. At least two egg-parasites of Nezara were found, one of which was more abundant than the other. In the species observed there is only one parasite to each egg, and in the great majority of cases seen the percentage of parasitism was 100. It sometimes happens that the parasite is unable to emerge, although it succeeds in preventing the development of the bug. The question of the relation of Nezara and the other plant bugs with their egg-parasites is one which requires considerable further investigation.

CONTROL MEASURES FOR NEZARA IN ST. VINCENT.

The following measures have mostly been referred to already, but are summarized here for convenience :—

1. Practice clean cultivation in cotton fields, keeping down weeds as far as possible, especially the weed commonly known as

*Reported by S. C. Harland.

'dove food' (*Polanisia viscosa*). The early stages of the green bug breed on this weed and transfer to the cotton later, and the adults go back to it to lay their eggs. This weed is usually growing and fruiting all the year round, and in itself is sufficient to keep Nezara going.

2. Keep the borders of cotton fields as free of 'bush' (i.e. miscellaneous weeds) as possible. The green bug breeds on a number of these weeds and then goes into the cotton fields. A grass crop on the borders would help to keep down the weeds.

3. Avoid inter-cropping leguminous crops, such as black-eye peas, with cotton. These are favourite food-plants of the green bug, and when the inter-crop is removed the bugs have a tendency to attack the cotton. The bugs infect these crops with the fungi of internal boll disease, and later carry this infection to the cotton boll.

4. It is inadvisable to grow a leguminous catch crop ahead of cotton, unless it is for the purpose of an observation crop to get an idea of the probable abundance of the bugs for the season. Such a crop should be watched carefully, and the bugs controlled by collecting.

5. Keep a lookout for the egg-parasites of the green bug which are quite efficient if encouraged. Freshly laid egg-masses are straw-coloured, and, if unparasitized, remain this colour for four or five days and then turn salmon-pink a day or two before the bugs hatch. Destroy these. Parasitized egg-masses of the green bug turn a dirty buff colour after three or four days, and eventually become quite blackish, the parasites emerging in about ten days.

A certain number of the parasites can be liberated in the fields where leguminous crops or cotton are grown, and, if abundant in any district, can be distributed to districts which need them.

6. Collect the bugs wherever possible. The adults are pea-green, without any conspicuous markings.

7. Keep a lookout for any new infestation of the green bug during the pigeon pea season from December to February. Such an infestation is not of much danger to the cotton crop so late in the season, but unless an outbreak of this kind is controlled, it will leave a number of bugs to tide over the critical period before the rains come. If there is no marked dry period in March, it will be all the easier for the bugs to survive on the 'bush', which will never really die down.

THE LEAF-FOOTED TOMATO BUG (*Leptoglossus balteatus*).

This bug was found to be confined to the Kingstown district in St. Vincent. It was fairly common at the Experiment Station during November and December on tomato and bonavist, and was occasionally seen on other plants. The bug appears to be a fairly general feeder. The adults and young stages were occasionally seen upon the cotton plants at the Experiment Station, but never actually attacking the bolls. On an estate near Kingstown a young brood of this species was observed on a cotton stem with

the empty egg shells from which they had recently hatched. In the island of Batawia, however, there was a fair percentage of injury to cotton bolls as the result of the punctures of this species. and a small percentage of staining due to infection with internal boll disease. A reference to the table on page 9 of this number will indicate the percentage of injury. An account of the nature of the injury done by this bug is given by the Mycologist on page 3. The status of this bug in Batawia has already been alluded to elsewhere. This species was present in Bequia. For a further account of this bug reference should be made to the writer's report on his visit to St. Vincent, published in the St. Vincent *Government Gazette* for April 25, 1918.

THE RED TOMATO BUG (*Phthia picta*).

This bug was never actually found attacking cotton bolls in St. Vincent, but bagging experiments made by the Mycologist with this species indicate that it is capable of puncturing cotton bolls and infecting them with internal boll disease. These experiments, however, were not on a large enough scale to afford much information. In St. Vincent, Phthia was found only on tomato, bonavist, and a wild solanaceous plant (*Physalis* sp.). It is probably a fairly general feeder in the adult stage.

Neither of these tomato bugs is ordinarily abundant enough to be considered a pest in St. Vincent, but in the event of any sudden increase in numbers, the various stages should be collected and destroyed. This method of control is rendered comparatively easy owing to the fact that the younger stages crowd together on the under side of a leaf. They scatter very quickly at the slightest disturbance, but with reasonable care can be caught in masses. If disturbed they soon return to the same spot, and indeed appear to spend most of their lives on the same part of their food-plant.

THE PEA CHINK (*Edessa meditabunda*).

This insect is one of the two commoner species of 'bush bugs' in St. Vincent, the other being the green bug (*Nezara viridula*). These two bugs are collectively known as 'pea chinks' in Barbados, and this term is here suggested as a common name for Edessa. The word 'chink' is probably a corruption of 'chinch' or 'chinche', meaning 'bug'.

The pea chink seems to be fairly generally distributed throughout St. Vincent, and as far as the writer's observations go, was more generally abundant towards the end of 1917 than the green bug. Edessa has a wide range of food-plants, and a preliminary list would probably include nearly all those mentioned for Nezara.

As stated elsewhere, the pea chink cannot be regarded as a serious pest to cotton, since experiments by the Mycologist have shown that it hardly pierces the carpels or outer covering of the bolls, and does not infect the bolls with internal boll disease. This bug has a short beak as compared with that of Nezara, and this shortness of beak may partly account for its inability to pierce the rather tough covering of even young to half-grown bolls.

Nothing much is known at present about the relation of Edessa to its food-plants. The eggs are commonly laid on the under side of leaves of such plants as 'dove weed', tomato, and various legumes; on cotton they have been found on the inner side of the bracts. The adults have a habit of swarming on certain plants, such as pigeon pea, *Tephrosia* spp, *Indigofera* spp., etc.

The only natural enemies of Edessa which have been observed in St. Vincent are two species of egg-parasites. These did not appear to be very well distributed towards the end of 1917.

CONTROL MEASURES. The adults should be collected whenever possible, and advantage should be taken of their habit of swarming on certain plants. Their swarms consist mainly of mating pairs, and if taken at this time, a large amount of egg-laying will be prevented. The egg-parasites should be encouraged and distributed where needed.

OTHER PLANT BUGS.

There are several other species of plant bugs in St. Vincent which breed on 'bush' and on many of the cultivated plants given in the list of Nezara food-plants. These include such species as *Acanthocerus lobatus*, *Oncopeltus fasciatus*, *Thyanta perditor*, *Arvelius albopunctatus*, *Piezodorus guildingi*, *Euschistus crenator*, and *Sphyrocoris obliquus*. These bugs have not been investigated sufficiently for any definite statements to be made about their connexion with cotton under St. Vincent conditions. Some of them, however, or species closely related to them, have been found attacking cotton in the Southern United States and in other countries, so that they must be regarded with suspicion until something further is known of them. The life-cycles of some of them have been worked out by the writer under laboratory conditions. None of them was at all abundant in St. Vincent during November and December 1917, and some were observed to be effectively controlled by egg-parasites.

SOME EFFECTS OF COTTON STAINER CONTROL IN ST. VINCENT.

BY W. N. SANDS, F.L.S.,

Agricultural Superintendent, St. Vincent.

In the *West Indian Bulletin*, Vol. XVI, No. 3., and in the Report of the Agricultural Department, St. Vincent, for 1916-17, accounts were given of the measures adopted and suggested to control the cotton stainer (*Dysdercus delauneyi*, Leth.) in St. Vincent, in order that the extensive damage caused annually by this pest might be reduced, and the cotton industry placed on a more stable footing.

Briefly stated, the measures adopted in the latter part of 1916 and the early months of 1917 consisted of the destruction of silk-cotton (*Eriodendron anfractuosum*) and 'John Bull' (*Thespesia populnea*) trees, perennial wild cottons, and by April 30 all cultivated cotton stalks. The collection of cotton stainers was also undertaken in some cases in or in the vicinity of buildings used as storehouses for seed-cotton and cotton seed, and in the neighbourhood of such of the native food trees named above as could not be completely destroyed before the end of April. Notwithstanding these efforts some insects were able to survive, and these formed in certain places the nuclei of infestations of adjoining cotton fields; however, large areas of cotton were free of the pest until the bulk of the crop of both first and second pickings had been reaped.

In the cotton plots at the Agricultural Experiment Station, where the cotton stainer was carefully searched for and systematically collected, there was a striking decrease in the number taken in the 1917-18 season, as compared with the previous season. The detailed record is given below :—

1916-17.		1917-18.	
Month.	No. of cotton stainers collected.	Month.	No. of cotton stainers collected.
July 1916.	2,696	July 1917.	0
Aug. ,,	13,554	Aug. ,,	0
Sept. ,,	6,181	Sept. ,,	0
Oct. ,,	806	Oct. ,,	0
Nov. ,,	1,028	Nov. ,,	0
Dec. ,,	16,015	Dec. ,,	25
Jan. 1917.	164,609	Jan. 1918.	0
Feb. ,,	Beyond control.	Feb. ,,	11,511

The loss of crop at the Station in the 1917-18 season due to the cotton stainer was estimated as nil, as picking was practically completed at the beginning of February 1918 when flights of these insects from a neighbouring estate started. It was not possible during this season to ascertain in a definite manner the increased yield of cotton due to the absence of the pest; it is shown, however,

by S. C. Harland*, that in the manurial experiment plots 48·2 per cent. of the flowers produced by the plants matured into bolls in 1917-18 as against 17·2 per cent. in the previous season, or approximately three times as many. This was due to a favourable season, as well as to freedom from insect attacks and fungus and bacterial diseases. It is estimated, nevertheless, that quite 50 per cent. of the increase in the number of bolls maturing was due to the fact that there were no stainers present.

No flights of the bug on any large scale were recorded during the development of the cotton crop in the island; moreover, average crops were produced in areas where this had not been possible for several years previously. These areas were situated more particularly in a district where 'John Bull' trees had occurred in large numbers.

In at least the last five seasons, the picking of the crop was finished by the end of January, and often by the middle of that month. On one or two estates small second pickings were made later than this, but it may be said that to all intents and purposes the crop was completed at this time and the bolls that remained were nearly all badly affected with internal boll disease, due to the attacks of the cotton stainer, which was always abundant in the fields everywhere. During the present season, however, the picking period was considerably extended throughout the island, and for the first time in many years good second pickings of white cotton have been obtained on many estates: this was entirely due to the absence of the pest, or the restriction of its occurrence to small numbers only appearing towards the end of the season in 1918. In places, pickings of white cotton were made at the end of March.

In former years some cotton fields were found to be heavily infested with the insect as early as the month of July, but this was nowhere the case this season, and it was found that only in those places where the pest had been allowed to tide over the close season was serious damage done. Another marked feature was, that in the absence of the cotton stainer average crops were obtained on certain estates even when a large percentage of the flowers and bolls which would have produced the so-called 'first pickings' were shed; the cotton in these cases being chiefly obtained from 'second pickings'. It may be explained here that what is known locally as 'first pickings' is the cotton produced in bolls formed on the primary sympodial branches of the main stem, and that which makes up the 'second pickings' is cotton from the secondary sympodia on the basal laterals or other monopodial branches. Most of it is from the first-named source.

The absence of the pest from large areas of cotton also allowed of the systematic study by the Mycologist and Entomologist of the Imperial Department of Agriculture of certain other plant bugs feeding on bolls, together with the nature and effects of their attacks, and the methods by which they might be controlled. Accounts of the results of the investigation are published in this Journal, pages 1-40.

*Manurial Experiments with Sea Island Cotton in St. Vincent, 1917-18; (not yet published).

The following information relating to the Sea Island cotton crops produced on certain estates in St. Vincent and Bequia during the 1917-18 season in the presence and absence of the cotton stainer was obtained.

Stainers Present Early.

Estate A (*Bequia*).

Twenty-seven acres were planted. The season was a good one and the rainfall well distributed. The growth and bearing of the plants were above the average. The crop that could reasonably have been expected was 4,550 ℔. of marketable cotton. The cotton stainer was present throughout the season. Fields generally were heavily infested. The actual yield obtained was 190 ℔. of white, and 347 ℔. of stained cotton. The first pickings were badly damaged by internal boll disease, and no second pickings were reaped. The disastrous result is to be attributed to the cotton stainer alone, as little damage was done by other bugs. The native food-plants of the cotton stainer were not destroyed on the island, but it may be mentioned that this work has since been performed by the Agricultural Department.

Estate B (*St. Vincent*).

The area planted amounted to 70 acres. The season and rainfall were satisfactory. The growth and bearing of the plants were below the average; still at least 8,000℔. of marketable cotton should have been picked. The cotton stainer as well as other plant bugs attacked the bolls persistently during the season, and these pests were very numerous. The amount of cotton secured was 1,904 ℔. of white, and 618 ℔. of stained. The first pickings were partially, and second pickings almost entirely destroyed. The cotton stainer appeared to have survived in the neighbourhood of the estate buildings on refuse seed-cotton, as it was found here in considerable numbers as late as the month of July. The proportion of the loss of crop due to the pest could not be ascertained owing to the presence of other bugs, but it probably amounted to quite 50 per cent. of the total.

Stainers only at End of Crop.

Estate C (*St. Vincent*).

Here 65 acres were cultivated. An early and severe infestation of the fields by the green bug (*Nezara viridula*) caused much boll-shedding and damage to the bolls that would have produced the first pickings. Only a few stainers were found and collected before the end of the year. In the month of November the probable crop was estimated at 3,600 ℔. of cotton only, owing to the loss due to the green bug. Fortunately the bug attacks decreased very considerably in intensity as the season progressed, and the bolls on the secondary branches, in the absence of an early or serious infestation of the cotton stainer, were able to mature. The actual outturn was 7,361 ℔. of white, and 1,046 ℔. of stained cotton.

Estate D (*St. Vincent*).

On this estate 103 acres were planted. The season experienced was a good one. The fields were satisfactorily cultivated, and

fairly well manured. The growth and flowering of the plants generally were good. A reasonable estimate of the crop which ought to have been obtained under these circumstances was 18,000 ℔. of cotton. Unfortunately there were early and persistent attacks of the green bug (*Nezara viridula*), and in all the fields severe damage was inflicted on the bolls which would have given the first pickings. In certain fields the larger proportion of the bolls was shed. The damage was not due to the cotton stainer as this insect only occurred in small numbers towards the close of the season. The quantity of cotton reaped amounted to 6,648 ℔. of white, and 853℔. of stained. Had the cotton stainer been present at an early stage of the crop together with the green bug, it is safe to say that the crop result, bad as it was, would have been far worse.

Estate E (St. Vincent).

A few facts relating to this estate, which planted 65 acres, are included here, because it shows the amount of cotton it is possible to produce in a good season on suitable land, thoroughly cultivated and moderately well manured, in the absence of attacks of the cotton stainer and green bug. At one period early in the season there was some boll disease, chiefly bacterial, in a field, but it had no marked effect on the cotton crop beyond increasing the quantity of stained cotton obtained from this particular field. The marketable cotton produced was 13,430 ℔. of white, 3,181 ℔. of stained, or at the rate of 255 ℔. of lint cotton per acre.

TABLE.

SUMMARY OF CERTAIN ESTATE RESULTS 1917–18.

Estate.	Acres planted.	Crop expected in lb. of lint cotton.	Crop obtained in lb. of lint cotton.	White cotton in lb.	Cotton classed as 'stains'* in lb.	Percentage of 'stains.'	Yield per acre in lb.	Remarks.
A	27	4.550	537	190	347	64·6	19	Early, severe, and persistent attacks of cotton stainer.
B	70	8,000	2,522	1,904	618	24·5	36	Green bugs and stainers present all the season.
C	65	3,600†	7,361	6,315	1,046	14·2	113	Early attacks of green bug. Some stainers appeared late in season.
D	103	18,000	7,501	6,648	853	11·3	72	Severe attacks of green bug during the season. Little damage by stainers.
E	65	13,000	16,611	13,430	3,181	19·1	255	No green bugs or stainers until near the end of season.

*Some of the cotton classed as 'stains' contains a fairly high proportion of white lint.

†Estimated in November after green bug attack.

The first two of the above examples show quite clearly the very serious effects of the attacks of the cotton stainer on the yield of cotton, and the others supply further evidence, if such were needed, of the beneficial results of the control of the pest.

It would be difficult, and perhaps impossible, to arrive at even an approximate estimate of the increased yield and value of the 1917-18 Sea Island cotton crop of St. Vincent, which might be attributed to the measures adopted for keeping the cotton stainer in check, but it can be confidently stated that in value alone, cotton growers benefited to the extent of several thousand pounds sterling.

In order to reduce still further the chances of the cotton stainer surviving the period between the destruction of the old cotton stalks and the flowering of the succeeding crop, two important additions were made to existing Ordinances. The first consisted of an Ordinance to supplement the provisions of the Cotton Stainer Ordinance, 1916, which was published in the *West Indian Bulletin*, Vol. XVI, No. 3, pp. 253-54. Section 2 of the supplementary Ordinance passed by the Legislative Council on February 11, 1918, reads as follows :—

'The occupier of any building, in or in the neighbourhood of which the cotton stainer is present, who fails to take all such measures as may be necessary for the destruction of such cotton stainer on becoming aware, or being notified, of the presence of the same, in, or in the neighbourhood of such building shall be liable on summary conviction to a fine not exceeding twenty pounds, or, in default of payment, to be imprisoned with or without hard labour for a term not exceeding six months.'

The second was an amendment to the Cotton Diseases Prevention Ordinance, 1911. Sections 2 and 3, as enacted on February 11, 1918, are as under :—

'For the definition of "Cotton Season" in section two of the Principal Ordinance, the following definition shall be substituted :—

'"Cotton Season" means such period as the Governor may by Order in Council prescribe, either for the whole of, or for a particular area of, that part of the Colony to which this Ordinance applies or may for the time being be applied, and, except in so far as such period is so prescribed, shall mean the period between the last day of April in any year and the first day of April in the succeeding year.

'"Any person who plants or causes to be planted cotton except during the cotton season shall be deemed to be guilty of an offence against the Principal Ordinance."'

The first amendment was the outcome of observations made during the period from May to September 1917. It was found, as previously mentioned, that the pest was able to survive in places adjacent to buildings on estates and in other situations where refuse seed-cotton and cotton seed had been scattered about and not collected and burnt.

The second amendment was made necessary by the fact that under the existing law there was actually no close season for cotton in St. Vincent, and old cotton stalks could be destroyed on April 30, and seed of the succeeding crop sown on May 1.

Although the primary object of the original Ordinance was the control of the leaf-blister mite (*Eriophyes gossypii*), and in this its operation has met with success, yet it was necessary also, owing to the fact that under certain conditions the cotton stainer was able to exist for some time without breeding on non-malvaceous plants, to provide that the month of April in each year should constitute a definite close season. By adopting this course the cotton stainer will be deprived of agreeable food for a period of three months at least, that is, from April 1 to July 1, at which latter date any cotton sown on or about May 1 would start to flower. In this connexion it may be recorded that in experiments made by the writer it was found possible to keep the cotton stainer alive in the laboratory for a period of two months by feeding it on the juice of freshly sliced sugar-cane. It is desirable to state, however, that insects so kept were not infected with the parasitic mite which causes some deaths among the pest in the field and the laboratory, more especially when the insect is in an impoverished condition owing to lack of suitable food and moisture.

Observations relating to the pulling up and burning of cotton stalks have shown that, provided the heaps of stalks are not left too long, they can be made to act as traps for the cotton stainer in the field. In fine dry weather the stalks can be burnt effectively, with the insects which have collected on them, within three days of their being pulled up. All that is necessary is to start the fire with some dry bush or trash. If the stalks are allowed to remain for several days without being fired the cotton stainer leaves them and seeks shelter and food elsewhere.

There were few other developments connected with the pest during the past season. The position of it in the Grenadine islands of Batawia and Bequia in relation to the cotton grown in these places is described in the papers of the Mycologist and Entomologist. It will be necessary to follow up the investigations in the Southern Grenadines where no control work has been attempted, because these islands are producing increasing quantities of Sea Island cotton and decreasing amounts of 'Marie Galante'. It would appear that the cultivation of the early maturing Sea Island cotton crop jeopardizes the 'Marie Galante' crop which follows it, owing to the cotton stainer breeding on the Sea Island cotton, and then transferring itself to the 'Marie Galante', and causing similar extensive damage as in the case of Sea Island cotton.

At Bequia last season, a field of 7 acres of 'Marie Galante' cotton grown in the neighbourhood of Sea Island cotton was a total failure owing to internal boll disease following attacks of the cotton stainer.

The work of eradicating any growing stumps and seedlings of silk-cotton and 'John Bull' trees, the chief nurse trees, was closely followed up, and the whole of St. Vincent was dealt with during the first four months of the present year, 1918.

The gratifying measure of success which has attended the energetic and far-reaching efforts made in St. Vincent to control the cotton stainer has already had a most beneficial effect on the local Sea Island cotton industry.

NOTES ON TRAPPING THE COTTON STAINER IN ST. VINCENT.

BY W. N. SANDS, F.L.S.,

Agricultural Superintendent, St. Vincent.

In the *West Indian Bulletin*, Vol. XVI, No. 3, following an account of the life-history, feeding habits, and methods of control of the cotton stainer (*Dysdercus delauneyi*, Leth.), a short description was given of the use of a gasolene torch for destroying the pest when it had been collected on traps. The following additional notes on methods adopted in certain situations where it was necessary to destroy the insect may be of interest.

During the period between the destruction of the old cotton stalks and the commencement of the flowering of the new crop, that is, approximately, May 1 to July 15, it is particularly necessary to search for and kill the cotton stainer in order to prevent early infestations of young cotton fields.

As the result of the campaign previously described, all fruiting 'John Bull' (*Thespesia populnea*) and silk-cotton (*Eriodendron anfractuosum*) trees, and perennial cottons were recently destroyed. These were the chief nurse trees in the close season; but it is important to note that the pest can exist for at least a month without breeding on other plants. As an example, the writer has observed the adult insect feeding on the flowers of the black sage (*Cordia cylindristachya*) over a period of five weeks after the cotton stalks of an adjoining field had been burnt.

It is proposed to give an outline of the efforts and experiments made in the vicinity of the Botanic Gardens, St. Vincent, in the months of May and June 1918, to trap the cotton stainer when and wherever found. Cotton fields were situated close to the gardens on three sides, namely, to the east, south, and west. The old stalks in the fields were destroyed towards the end of April. At this time the pest was present in considerable numbers. It was the usual practice to allow the stalks to dry thoroughly before burning them. It was thought that the heaps, if dealt with as soon as possible after they were pulled up, might be made to act as traps for the pest, and so prevent it from leaving them. The experiment was tried, and it was found that quite large numbers of the insect could be caught, if the heaps were fired within three days after the stalks were pulled. The weather must be fine to make this practicable, and a handful of dry trash is required to start the fire. It happened that the insect in one part of the gardens took shelter from a field on a hedge of wild coffee (*Aralia Guilfoylei*), and under the leaves of sago palms (*Cycas circinalis*); they were enticed from these places on to heaps of cotton seed placed at intervals on the ground. When on the seed they were killed by means of a 'Primus' kerosene torch. In these experiments the kerosene torch was used throughout, and it was found to be quite as effective as the gasolene one already referred to.

The pest from another field was attracted to three large trees of cork wood or bois flot (*Ochroma lagopus*), which were ripening their fruits at the beginning of May. It had already started to

breed when discovered. Eggs were found in the soil near the base of the trees, and many insects in early stages of growth were seen. Adult stainers were feeding on the open and unopen fruits on the branches. The fruits were collected and used as traps. The unopen ones were used chiefly, as these were not so readily damaged by the torch. After each application a few of the unopened fruits were split asunder in order to attract immature insects as well as the adults. The knowledge of the life-history of the pest previously gained was most helpful in indicating the best manner of placing the traps. It was known that the eggs are laid in the soil under the food-plants, and in the case of large trees, such as the bois flot, silk-cotton, and 'John Bull', round about the bases of their trunks. The traps were set, therefore, close to the stems of the bois flot trees, and the young stainers on hatching were quickly attracted to the traps. The adults also on descending the trees had little difficulty in finding the heaps of food.

When the pest occurred in large numbers, and it was necessary to deal with it as soon as possible, the traps were flamed at 7 a.m., noon, and 4 p.m. In wet weather the traps, whether of cotton seed or bois flot fruits, were found to be less effective than in fine weather, because the insects then take shelter under leaves and in dry situations. On fair days the largest numbers of insects were killed in the mid-day operations.

Shortly after the operations with the bois flot trees were finished, another tree, the Tobago bread-nut (*Pachira aquatica*), growing in the old Botanic Gardens now included in Government House grounds, was found to be infested with the pest, and steps had to be taken to deal with a group of large trees and saplings in forest land with a thick undergrowth of bush. The first work undertaken was the cutting down of as many of the trees as could be spared, without affecting an important spring of water; the collecting of all fruits and seeds, and the clearing away of undergrowth. The seeds which had not germinated were placed in heaps to act as traps. The insects collected on them, but not so readily as was expected, and cotton seed and cotton-seed meal were substituted, with the result that a remarkable preference was shown for these products even in the presence of a large supply of Tobago bread-nut seed. Within one hour of being placed near the bases of standing trees, the cotton-seed traps were covered with the insect in all stages of development. As the weather was wet at the end of May, it was found necessary to put down fresh seed or meal every two or three days, to maintain the attractiveness of the traps. Cotton seed possesses certain advantages over meal in that it lasts longer under exposure, and stands the heat of the torch better.

As noted in the case of the bois flot trees dealt with, a large number of egg-masses were found in the soil near the bases of the Tobago bread-nut trees.

Both the bois flot and Tobago bread-nut trees were referred to in the paper (loc. cit.). The bread nut tree can be readily dealt with as only a few specimens exist in the colony, but the bois-flot is widely distributed. Fortunately the seeds are

very small, and much sought after by rats and mice. The fruits also, even before they open, are attacked by the manicou (*Diadelphys* sp.). The floss in which the seed is embedded is to a large extent collected by people for use in stuffing cushions and pillows, but if it is seen that the trees are not desired for this purpose it may be found necessary to destroy them.

Another method of trapping, adopted where the cotton stainer had taken shelter in hedges bordering cotton fields, was to hang balls of seed cotton at intervals in the hedges, and when the insect had collected on them to shake them off into a pan containing kerosene oil and water. This is a useful method in the absence of a torch, or when there is a difficulty in obtaining boiling water to deal with the insect on traps on the ground.

When cotton seed was being crushed at the Government ginnery for oil extraction purposes, the ginnery served as a centre of attraction for the pest in the district. In May and June it reached the buildings in considerable numbers. Only adult forms arrived, and some of these had obviously been feeding in the interim on flowers of the aromatic wild sage (*Cordia* sp.) and had become imbued with a most objectionable 'bush-bug' smell. As a rule the cotton stainer is practically odourless.

It is often inadvisable to use a torch near buildings of an inflammable nature, so that here the insects had to be controlled chiefly by means of boiling water. In rainy weather, however, large numbers were killed on the walls of the buildings, to which places they had crawled from cotton seed on the ground in order to seek shelter. A wooden lath was found very useful for this work, although a wire 'fly swatter' would probably answer equally as well. As a result of the measures adopted the insect was unable to breed.

Adults can readily fly long distances in search of food, and migrations are particularly noticeable after a shower of rain following a spell of dry weather. The immature insect can also roam far, and wingless forms of the fourth instar have been known to walk from old cotton plants to a plot of young bolling plants over a distance of 130 yards. It is quite possible that even longer journeys than this can be made, so that if no other food is allowed to exist in the neighbourhood of traps, these are effective over a considerable area, which is a most important point.

In all trapping work where attractive food substances are used, and the stainers are numerous, it is essential that the traps be inspected daily. If this is not done, egg-laying takes place, and the time required to eradicate the pest is lengthened considerably.

NOTES ON THYMOL CONTENT OF HORSE-MINT (*MONARDA PUNCTATA*) AND AJOWAN SEED (*CARUM COPTICUM*).

BY

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HORSE MINT OIL.

A sample of oil distilled from the American Horse-mint (*Monarda punctata*), forwarded by Mr. W. Robson, Curator, Botanic Station, Montserrat, has been recently examined at the Government Laboratory, Antigua, with the following analytical results:—

Specific gravity at $\frac{28}{16}\cdot 6$ C. = 0 928
Sugar scale (Ventzke)
Polariscope reading 100 mm. tube = −3·2 at 28° C.
Whe ce angular reading = − 11° 5·4
Refractive index at 28° C. = 1·501
Phenols per cent. 60·4
Non phenols per cent. 39 6.

From the data supplied by Mr Robson, it appears that 184 ℔. of growth were obtained from the experimental plot, corresponding to a yield of 4,416 ℔. per acre.

Distilled in an ordinary Bay oil still, 159 ℔. of these tops gave the following results:—

1st hour	111 c.c.
2nd ,,	52 c.c.
3rd ,,	15 c.c.
4th ,,	9 c.c.
5th and 6th hour	13 c.c.

The oil obtained in the first hour had a decidedly reddish tinge, but that coming over in the second hour was of a pale lemon-yellow colour.

The bulked sample consisted of a clear lemon-yellow oil with a decisive smell of thymol.

The phenols were estimated in the usual way by shaking up repeatedly with definite quantities of approximately 5 per cent. soda, until no further absorption was noticed. On acidifying with dilute sulphuric acid the phenols separated out as an oily layer, and on adding a very small crystal of thymol to the oily liquid so obtained, the thymol rapidly crystallized out, a yield of 44 per cent. by weight of the pure dried crystals being obtained on the original oil.

From Mr. Robson's figures a calculated yield of 4·34 oz. of the oil per 100 ℔. of the leaf was obtained, but apparently no attempt was made to separate the dissolved oil from the distillate water. The latter is stated to carry 0·11 per cent. of oil (actual

figures obtained at the Government Laboratory, Antigua, show 0·07 per cent. oil) containing 95 per cent. phenols. This corresponds to a yield of 0·27 per cent. of oil, which agrees fairly well with the results obtained by Hood, ('Commercial Production of Thymol from Horse-mint (*Monarda punctata*)' : *Bulletin 372*, U.S. Department of Agriculture, May 1916,) where the following abridged data are published.

Yield of oil and total phenols from horse-mint at different stages of growth.

Stage of growth.	Weight of herb distilled in lb.	Actual yield.		Yield per acre.		
		Oil, per cent.	Total phenols, per cent.	Herb, in lb.	Oil, lb.	Phenols, lb.
Plants just beginning to send up flower stalks	453	·31	72	9,690	32·94	23 05
Budded stage	506	·30	76	10,590	31·77	24·14
Full flower	1,403	·24	74	10,000	24·0	18 48
Flower fallen	352	·18	74	8,500	15·30	10 82

If the amount of oil dissolved in the distillate water had been taken into account, the yield would probably have more closely approximated that from the best results quoted above.

From Mr. Robson's figures for Montserrat, and the data obtained at the Government Laboratory, Antigua, it would appear that a good average crop of horse-mint will yield 80 oz. of thymol per acre, which at recent quotations would be worth from $89 60 to $116 (October 1917 market values for thymol being in the United States $1·45, in London $1·12 per oz.). The results are not so high as those obtained in Florida, where the oil is reported to yield 92 to 96 per cent. phenols and 64·3 per cent. commercial thymol. The yield per acre is also considerably less, namely, 4,416, the Florida yield being estimated at from 13 to 19 lb. thymol per acre. With the present high price of thymol the cultivation and distillation of this herb in the West Indies should be a profitable undertaking.

Ajowan Seed Oil.

About 10 lb. of ajowan seed (*Carum copticum*), grown in Montserrat, were received from the Curator in May and June 1917, for experimental distillation and determination of the thymol contents of the oil.

After several preliminary distillations a satisfactory type of apparatus was evolved, in which the seed was jacketed with water at boiling point, and steam passed into the still from two nozzles facing each other; even then the rate of distillation was comparatively slow, requiring eight hours to distil all the volatile oil from a weighed sample of seed.

In actual practice, for manufacturing purposes, the seed is placed in shallow trays, over and through which superheated steam is passed, the condensate water being returned to the body of the still.

This condensate water was found by actual experiment to yield 0·05 to 0·07 per cent. of volatile oil.

In the experiments under review, the total amounts of oil received from the seed were, respectively, 2·74, 3·0, and 3·1 per cent., while the seed itself was found to contain 12·4 per cent. of water. In the following table the percentage of the oil on air-dried and steam-dried seed is recapitulated :—

Percentage on air-dried seed.	Percentage on steam-dried seed at 100° C.
(1) 2·7	3·12
(2) 3·0	3·42
(3) 3·1	3·54

The results quoted above appear to be higher than those obtained in Ceylon where, according to the *Tropical Agriculturist* for October 1916, an oil content of 2·2 per cent. was obtained. The latter however was stated to contain 61 per cent. of thymol, which is considerably above the average, 40 to 55 per cent. being the amount usually contained in commercial oil (vide *Perfumery and Essential Oil Record*, August 1915, p. 255). According to this account the yield of oil from 100 ℔. of ajowan seed varies between 3 and 4 ℔.

It will be seen from the above that the yield of oil from the seed grown in Montserrat compares favourably with that obtained from the normal sources.

The following data were obtained from samples of oil distilled from seed grown in Montserrat and St. Kitts, respectively :—

	Montserrat.	St. Kitts.
Specific Gravity at $\frac{39}{16\cdot5}$ C.	0·9112	0·922
Sugar scale (Yentzke)		
Polariscope reading 100 mm. tube	= + 3·2	too dark
Whence angular reading ...	= + 11° 5·4	
Phenols	47·3 per cent.	53·0 per cent.
Non-phenols	52·7 „ „	47·0 „ „
Thymol recovered	43·5 „ „	...

The seed received from St. Kitts was somewhat old, having been gathered five months previous to analysis; it only yielded 1·7 per cent. of volatile oil on distillation.

From data published by Mr. Robson (Report on the Agricultural Department, Montserrat, 1916-17, p. 26), under favourable conditions a calculated yield of 1,129 lb. of cleaned seed was obtained per acre, which should yield according to the above results 35 lb. of oil. On the assumption that 40 per cent. thymol was recoverable, this would indicate a yield of 224 oz of thymol.

At the present market selling rate of thymol (October 1917 in London, \$1·12 per oz., in the United States, \$1·45 per oz.) this would indicate a theoretical yield per acre of from \$250 to \$324.

These prices are however abnormally inflated owing to the war, the anti-bellum quotations in 1914 being \$2 per lb. wholesale, at which value the yield per acre would work out at \$28. It is however quite likely that the high rate for drugs and chemicals will continue for a considerable time after the war.

Report on Ajowan Seed from Montserrat.

The following report on a sample of ajowan seed, grown at the Botanic Station, Montserrat, and forwarded to the Imperial Institute for examination, is of interest:—

The sample of ajowan seed which is the subject of this report was forwarded to the Imperial Institute by the Curator of the Botanic Station, Montserrat. It was stated that the seed had been grown experimentally in the island, and that it was desirable to ascertain its value as a source of thymol.

Description of sample. The sample weighed 18 lb., and consisted of ajowan seed of good average quality.

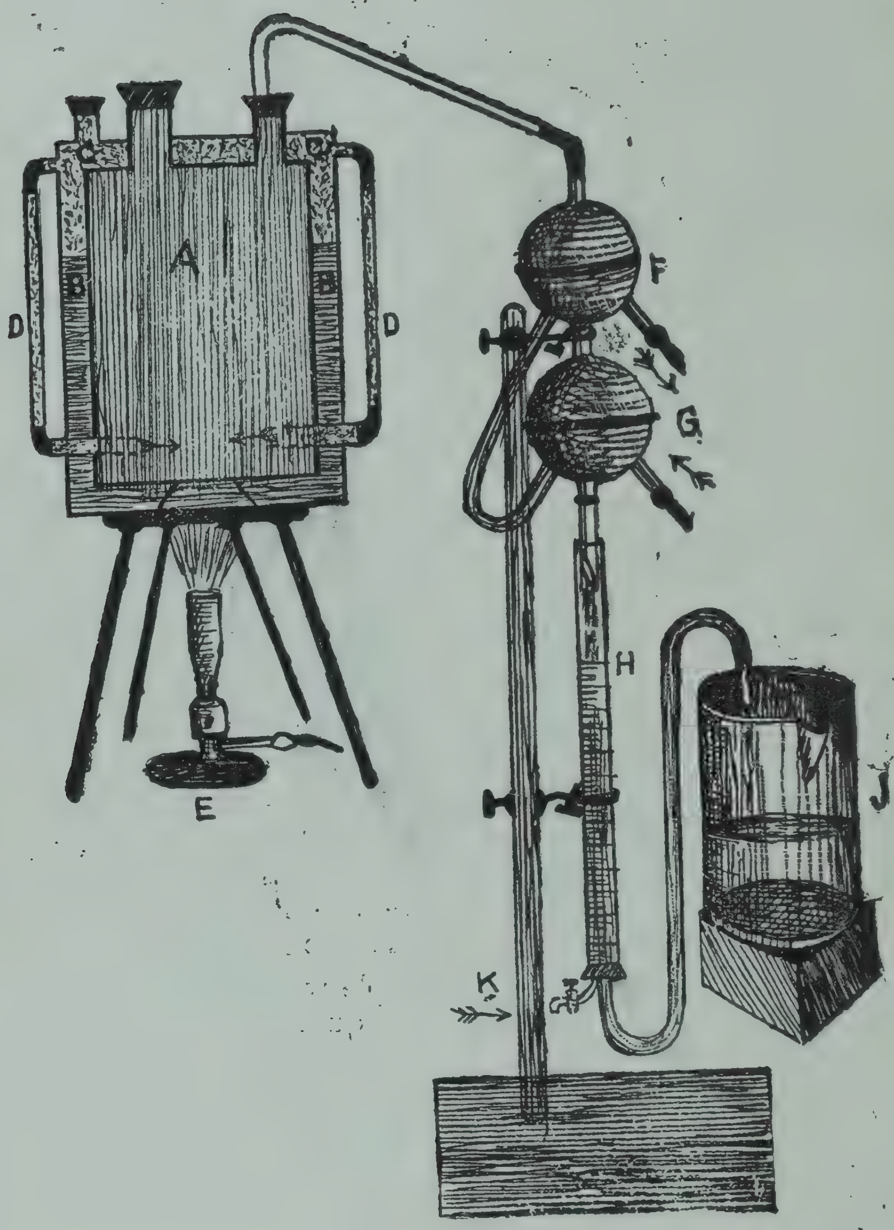
Results of examination. The seed as received contained 7·9 per cent. of moisture, and yielded 3·1 per cent. of a pale yellowish-brown oil. The oil was submitted to chemical examination, with the following results:—

	Present sample.	Figures recorded for normal ajowan oil.
Specific Gravity at 15°/15° C.	0·925	0·90 to 0·93
Optical rotation in a 100 mm. tube	+0·90°	+1° to +2°
Thymol per cent.	54	40 to 55

Ajowan seed usually furnishes from 3 to 4 per cent. of volatile oil, so that the yield in the present case is somewhat below the average; on the other hand, the percentage of thymol in the oil is much about the amount usually present.

Commercial valuation. The seed was submitted for valuation to three firms of manufacturing chemists, with the following results.

(1) One firm stated that the seed did not contain so much oil as is usually found in Indian ajowan seed of good quality, but that this should not appreciably detract from its value as a source of thymol. They were of opinion that as large quantities



STILL AND RECEIVER USED IN DISTILLATION OF AJOWAN SEED.

A. Inner chamber of still: to be filled with material to be distilled.

B.B. Boiling water.

C.C. Steam.

D.D. Steam pipes with inlets at base of A.

E. Gas burner.

F.G. Ordinary double brass condenser, with water inlet and outlet indicated by arrows.

H. Graduated receiver, made from a discarded burette.

J. Overflow receiver,

K. Tap by which distillate oil can be drawn off.

of thymol are now being produced in India, it would probably be essential for growers in Montserrat to undertake the distillation of the seed locally, as the heavy freight charges on the seed if shipped to Europe, would make competition with Indian thymol impossible.

The firm stated that under the present abnormal conditions, ajowan seed oil containing about 50 per cent. of thymol would probably realize not less than 10*s.* per lb.

(2) A second firm also expressed the opinion that it would be more economical to distil the oil in Montserrat than to export the seed, provided that the distillation were carried out in a satisfactory manner. With reference to the value of the seed they stated that Indian ajowan seed is not coming forward very freely to the London market at present, but that some time ago when thymol was selling at 25*s.* to 30*s.* per lb. they were able to buy considerable quantities at £15 per ton. The present value of thymol crystals is from 40*s.* to 50*s.* per lb. in London, so that consignments of seed would be expected to realize a higher price than that mentioned above.

(3) The third firm stated that the percentage of thymol in the oil from this seed is satisfactory, and that as the seed is of normal appearance, there should be a good market for it in competition with Indian ajowan seed. In view, however, of the difficulties of freight, and the competition of thyme oil from Spain, the firm considered that if the distillation of the seed could be carried out in Montserrat economically, it would be better to export the oil rather than the seed. They added that oil yielding 50 per cent. of thymol would probably be worth 15*s.* per lb. in the United Kingdom at the present time.

REMARKS.

The results of the examination of this sample of ajowon seed appear to indicate that the seed could be cultivated in Montserrat as a source of thymol. The actual yield of ajowan seed per acre in countries where it is already grown does not appear to be on record, so that no comparisons on this point are possible. The distillation of the seed for the production of oil should offer no difficulty, being a simple operation in itself and requiring little initial outlay (see *Bulletin of the Imperial Institute*, Vol. XII (1914), p. 599).

It is questionable whether the cost of harvesting the seed could be avoided, as suggested by the Curator of the Botanic Station, by distilling the whole plant, as it is difficult to remove the volatile oil entirely from the seed unless the latter is crushed before distillation. It is also possible that the other parts of the plant might furnish volatile oil which would unfavourably affect the composition of the oil obtained, and lower the percentage of thymol present.

It must be borne in mind in connexion with this subject that the market value of thymol is abnormally high at present, and that a considerable fall in price must be anticipated after the war. The current values cannot therefore be taken as a basis for future operations. Before the war thymol made in Germany was sold in London at about 7*s.* per lb.

SOME OBSERVATIONS ON FISH POISONING IN THE BRITISH VIRGIN ISLANDS.

BY T. L. E. CLARKE, M.D.,C.M.,

Medical Officer.

Throughout the West Indies, fish forms an important article of the diet of the inhabitants. Indeed the poorer natives regard it as their staple food. Such is the situation in the British Virgin Islands. The waters surrounding them abound in fish. Meat is not easily procurable, and when the native cannot obtain fish he hardly ever indulges in a meat diet, preferring in such cases to resort to his provision plot for his principal daily meal.

The Tortola *Bule Book* for 1841 lists about 100 kinds of fish, which are referred to as commonly caught in these waters and used for food. A note is added, 'the quantity of fish in these islands is very great and the quality good.'

Fish, both in the fresh and in the salted condition, are exported. It is impossible to state with accuracy the value in money of the fresh fish exported, for, as the fishing boats have no live-wells, and are all propelled by sails, the Government, to facilitate trade in this commodity, allows them to take out what is called a 'fishing permit' or a 'fishing clearance', and to proceed direct from the fishing grounds to the neighbouring islands of St. Thomas and St. Croix, without having to return to port and obtain a clearance from the Customs. The value of the fresh fish thus exported cannot therefore be obtained. Fresh fish, however, to the approximate value of £425, is annually exported through the Customs, so that, in the opinion of the writer, the actual value of exported fresh fish would approximate £1,000.

Salted fish, to the annual value of approximately £150, is also exported. The method used in its preparation is very simple. The fish is split dorsally from head to tail along and parallel with the line of the backbone, which is then freed from the half to which it is attached but not entirely removed, being left adherent to the dorsal rim of the latter half. The viscera are removed, and the fish thoroughly cleaned. Longitudinal incisions are then made through the flesh and through the bones of the head, from the inner cut surface nearly to the skin, and into these incisions, usually $1\frac{1}{2}$ to 2 inches apart, pounded common salt, locally obtained, is thoroughly rubbed. The fish are then put into brine, removed the next day, and suspended to drain and to dry in the sun for a day or two. They are taken down when dry, and packed in boxes or barrels ready for shipment. Fish prepared in this manner can be kept for months. Their quality is good, and *Lachnolaimus maximus*, locally known as 'hog-fish,' is especially palatable when cured by this method.

From the foregoing observations it is obvious that the subject of fish phisoning, with its concomitant problems, is of paramount importance, and one which deserves more investigation from the scientific point of view than the prevailing literature would lead one to believe had been accorded to it. But, as W. R. Dunlop points out (*West Indian Bulletin*, Vol. XVI,

No. 2, p. 159), there has been no systematic enquiry on this important subject, and the co-operation of the marine biologist with the medical investigator is necessary for its success. The writer merely desires to record his experiences during six years' residence in the British Virgin Islands, in the hope that they may subserve some useful purpose.

In the British Virgin Islands the following fish have been known to give rise to poisonous symptoms. The local names are used, and where possible to identify the scientific name, it has also been given.

Pompus or Toadie.

(*Spheroides Splengeri.*)

This fish frequents shallow and muddy creeks. It is not more than 6 to 8 inches long. The back is black or brownish-black: the belly is white, rough, and covered with tiny black spots. It is scaleless. It has no ventral fins, only one dorsal fin posteriorly situated, one anal fin, and one pectoral fin on each side When the least stimulus is applied to it, it inflates itself to an enormous degree. This fish is recognized as being extremely poisonous, and is never used for food. If given to an animal it is said to produce severe symptoms of poisoning, and often death results. Pigs have been killed from eating this fish.

Yellow-billed Sprat.

This fish belongs to the family Clupeidae, and is probably *Clupea Thrissa*. It is used for food, but not extensively, on account, probably, of the fact that there are many other fish available more palatable, and which have not its doubtful reputation. Two cases of poisoning by this fish have come under the personal observation of the writer. They occurred in the same locality to different persons, and at about the same time of the year, one case having occurred in the month of August, the other in the month of September.

Guinea Bird Shellfish.

This fish belongs to the family of the Ostraciidae, and is probably *Lactophrys bicaudalis*. Other members of this family are caught in these waters and are locally termed the 'horned shellfish' and the 'round belly shellfish.' Inasmuch as these fish are abundant, are universally consumed for food, and are regarded as of an excellent quality, but at the same time can give rise to severe toxic symptoms, they are worthy of more than a passing mention. The body is covered by a bony carapace composed of polygonal plates firmly joined together. The only parts free and moveable are the bases of the fins and the caudal peduncle from the point whence it emerges from the carapace. There is within the carapace just posterior to the head, and also near the caudal extremity, a small quantity of gelatinous material. This 'jelly', as it is termed, produces toxic symptoms, and in two cases seen by the writer has caused a condition not unlike that produced by the imbibition of large quantities of alcohol. The patients themselves thus describe their feelings,

and this description coupled with their staggering gait, would, had a history of alcoholism and the characteristic odour been present, have been mistaken for that condition, if the symptoms produced by the ingestion of this 'jelly' were not so generally known and recognized in these islands It is, it may be stated, a locally recognized fact, that the 'jelly' of *Lactophrys bicaudalis* is very poisonous, while the gelatinous material found in the 'horned' and 'round belly' varieties is not so productive of toxic symptoms. It is interesting to note that the manner of the preparation of this fish for food is almost invariably by roasting it on hot coals. The 'jelly' is not removed until *after* roasting, a fact which appears to indicate to us that we are here dealing with a toxin that is not diffusible by moderate heat. A case has been reported to the writer in which the fish was boiled by one ignorant of its poisonous properties, and the soup thus made produced the toxic effects characteristic of the jelly of the fish, as described below. This case occurred in Montserrat, and was not seen by the writer, who, however, gives as his authority the victim of the incident whom he interviewed. It is certain that the 'jelly' in the 'horned' and 'round-belly' varieties has been eaten with impunity, but on the other hand, in a case when the cooked head of the 'Guinea bird' shellfish was fed to a dog, it produced in the first place a staggering gait, gradually passing into somnolence and drowsiness, deepening into sleep and coma, followed by the death of the dog within three quarters of an hour after the meal. While the dog was eating the fish a puppy caught up a portion of it and swallowed it. It did not die, but its gait became unsteady, and it eventually fell asleep. In neither of these cases was there vomiting, although in one of the two cases referred to among the natives there was a severe attack of vomiting. In this case, however, the individual had realized that he was suffering from poisoning, and induced the vomiting himself before consulting me. In the case described as having occurred in Montserrat, the patient says that one of his first symptoms was nausea followed by vomiting.

The 'Guinea bird' shellfish is easily to be distinguished from the non-poisonous varieties by the fact that it is covered by distinct round dark spots. The 'round belly' shellfish has white spots on the head, on a small space above the ventral surface, and on the tail, but not on the caudal fin, as is the case with the 'Guinea bird'. The 'horned' shellfish has no spots, and is more elongated in shape. Both the 'Guinea bird' and the 'horned' have bony processes at the caudal end of their carapace ventrally, while the 'round-belly' has none.

The 'Guinea bird' shellfish should be avoided as a food-fish.

Barracuda or Barracouto.

(*Sphyraena Barracuda.*)

This fish is generally considered to be of an exceedingly delicate quality, and a very tasty food-fish. In spite of this fact, many cases of poisoning have been caused by its ingestion. At least ten cases have been seen by the writer. The fish attains to a large size. Many specimens weigh from 25 to 30 lb., but the largest specimen caught in these waters actually weighed 43 lb.

It is also reported that barracudas caught in certain localities are invariably poisonous. One of these localities is situated to the north and north-east of Necker island, a cay to the north of the island of Virgin Gorda. Owing to the proximity of the Virgin Gorda copper mines, the natives attribute this toxicity to the fact that the fish feed on copper banks, or on other fish that feed thereon. Nor is this toxicity confined by them to the barracuda, but includes all fish caught in this region. No case of barracuda-poisoning caused by any but the larger specimens has been seen by the writer, nor has he ever heard of a case of barracuda-poisoning attributed to the smaller specimens of the fish. This, in conjunction with the fact that the fish seems to be more poisonous at certain seasons, lends colour to the 'spawning' theory of fish poisoning. An interesting case of poisoning was reported to the writer, who has no reason to doubt its authenticity. A barracuda was caught on a sloop off Ponce, Porto Rico, while the crew's breakfast was being prepared. A margate, an innocuous fish, that has not been recorded as ever having caused poisonous symytoms, was being boiled for the meal. Some of the crew had taken their portion and were eating it, when the freshly caught barracuda was being cleaned. At this juncture the man who was engaged in cleaning the fish threw into the pot some fat from the barracuda, as he desired to improve the taste of the meal. Every one who afterwards partook of the contents of the pot was poisoned. The rest of the fish was salted, and was sold to a sloop at San Pedro de Macoris shortly afterwards; it poisoned the entire crew of that sloop, and caused two deaths. It is a generally admitted fact that the large barracudas are to be regarded with grave suspicion. Many natives, however, while they refrain from eating them when fresh, never throw them away, but salt them, claiming that after they are salted no ill effects are observed.

OLD WIFE.

(*Balistes Vetula*, Linnaeus.)

This fish belongs to the family of the Balistidae. The waters surrounding the British Virgin Islands abound in this fish and it is almost every day to be found offered for sale in the local market. It is readily purchased, and seems to be generally regarded as unquestionably wholesome for consumption. The writer has, however, seen two cases of poisoning undoubtedly attributable to this fish, cases moreover in which the poisoning could not possibly be attributed to ptomaine-formation between capture and preparation for food.

HORSE-EYE CAVALLY.

(*Caranx latus.*)

The family of the Carangidae are regarded as containing many excellent food fish. They, however, are not *all* fit for food. *Caranx latus* is, undoubtedly, a most poisonous fish. The writer has seen many cases of poisoning by this species, and has never heard of a single case in which the ingestion of *Caranx latus* was not followed by toxic symptoms of greater or lesser

intensity. It should never be eaten. It is a recognized fact that members of this family undergo putrefactive changes rapidly, but in a number of cases of poisoning observed, poisoning took place after eating fish freshly caught and immediately prepared for food, where there was not the slightest chance of the formation of ptomaines. The fact may be stated that the writer has seen a freshly caught *Caranx latus* cause poisoning, while the remainder of the same fish having been salted, was eaten some days afterwards by the same individual and by others without producing toxic symptoms. The majority of the fisher-folk in the British Virgin Islands regard the fish as poisonous.

There are two other of the Carangidae family noted in these islands as possessing very toxic properties.

(a) The 'Grass Cavally'. This fish is never eaten, so far as the writer knows, although it is caught frequently.

(b) The 'Amber Cavally' or 'Amber Fish'. This fish is regarded as poisonous, but is often eaten by the natives. It may produce severe poisoning. The writer has personally seen an effect of a very remarkable character produced by poisoning by this fish. An individual of a very hairy type lost during an attack of poisoning by 'amber fish' every hair on his head and body. He is now recovering from his attack, and his hair is again making its appearance.

The writer regrets that the scientific names of the two last mentioned members of this family have not been ascertained by him.

Rock-Fish or Rock-Hind.

(*Epinephelus Adscensionis?*) (*Mycteroperca Apua?*)

The British Virgin Islands abound in this fish, and it is regarded as entirely harmless. At the same time, the following incident, which occurred in December 1914, has injured its reputation. There was caught on board the Government sloop, a short distance from the island of Anegada, a rock-fish weighing about 10 lb. It was at once prepared for the breakfast meal. This meal took place about an hour afterwards when the sloop was at anchor at Anegada. There were seven persons on board: the captain, four sailors, and two passengers. The captain did not eat any of the fish, and one of the passengers after tasting a mouthful, remarked that its taste was peculiar, and refrained from eating more. The other passenger and the crew ate freely of it, and were all severely poisoned. In one case there were thirty-six stools in the forty-eight hours after the ingestion of the fish, with severe griping, cramps, and tenesmus. This is the only case of poisoning by this fish either observed or reported, but is nevertheless worthy of mention.

Kingfish

(*Scomberomorus Cavalla.*)

This is a much prized and a very excellent food-fish caught in these waters. But, in the months of August and September 1912, not only in the British Virgin Islands, but also in the neighbour-

ing islands of St. John and St. Thomas, there was for a short time what may be termed an epidemic of kingfish-poisoning. Ten or twelve cases were seen here, while one of the St. Thomas newspapers referred to the prevalence of the trouble there. The 'mulatto' kingfish (*Scomberomorus regalis*) is also viewed with suspicion. I have seen no cases of poisoning since 1912.

Lobsters and Sea-Crabs.

Poisoning by lobsters and by sea-crabs has been occasionally observed, but it would seem that in these cases the poisoning was rather due to the fact that they had become stale than to any toxin present in the living animal. No case has been seen where freshly caught lobsters were used for food. In all cases there was present an urticarial rash.

James Duncan Gatewood refers to other fish as being questionable. While he refers to the suspicion with which *Lachnolaimus maximus* is regarded in the West Indies, he still is doubtful as to whether it ever is toxic. This fish is very plentiful in these waters, and is and has always been looked upon as an entirely innocuous fish. No case of poisoning by it is on record here. He also reports that *Auxis Thazard* or *Auxis vulgaris* has been reported as dangerous. Although caught in large numbers in these waters, no case of poisoning has been laid at their door. Cases have, however, been reported where death has resulted to dogs and cats from eating the viscera. He seems to regard as dubious certain of the Lutianidae, or snappers. While the writer has not observed any cases of poisoning attributable to this family, it has been told to him that a deep-sea snapper whose scientific name he cannot place, is a suspicious variety. It is known locally as 'red-eye' snapper, but as no specimen has been seen by him, he cannot describe it.

An attempt has been made in the foregoing pages to describe the varieties of fish which, from the personal observation of the writer, have given rise to toxic symptoms resulting from their ingestion into the stomach. We know that poisoning by fish may be consequent either on consumption of the fish for food, or on wounds produced externally by the fish. As regards the latter, such wounds can be produced by many varieties, notably by the 'Lion fish' (*Scorpaena grandicornis*) by its dorsal spines; by the 'canaul' (*Holocentrus Ascenscionis*) in the same manner; by the 'doctor fish' (*Teuthis caeruleus*) and the 'barbeaux' (*Hepatus dussumiori*) by their caudal lancet-like spines; by species of the families Tetrodontidae and Diodontidae (globe and porcupine fishes), and by the spines of the sea-egg. Also nasty wounds can be produced by the teeth of *Sphyraena barracuda* and by the Muraenidae. A painful sting can be occasioned by contact with the Portuguese Man-of-war. Wounds and stings of this nature are frequently observed. There are also many varieties of fish belonging to different families which are poisonous, but are never eaten. The writer desires, however, to deal mainly with those fish which are generally regarded as innocuous, and are consumed by man for food, but which nevertheless, often give rise to toxic symptoms. He considers such information more valuable from a practical point of view.

Fish poisoning due to the ingestion of the fish as food may be due to two causes :—

(a) Toxins present in the body of the living fish.

(b) Toxins produced after the death of the fish by putrefactive changes, in other words, ptomaines. L. L. Mowbray (*Zoolcgical Society Bulletin*, Vol XIX, No. 6, of November 1916) publishes an article entitled 'Fish-poisoning (Ichthyotoxismus). Is this not simple ptomaine poisoning?' The idea that fish poisoning is *wholly* due to putrefactive changes in the fish resulting in the production of ptomaines before the fish is prepared and consumed for food is, in the light of the writer's experience, absolutely untenable. There have been already described in the preceding portion of this article cases in which poisoning has resulted from the ingestion of freshly caught fish, cases in which the fish was eaten almost immediately after capture. On some of these occasions the writer himself was present, and saw what happened. The opening paragraph of the article above referred to states: 'Among fishes eaten by man the species most likely to be dangerous as food during the season May to October are the barracudas, two species of kingfish, three species of jack, red rockfish, and tiger rockfish.' In the first place, if, as he states, these fish are considered to be dangerous, and, in his opinion, the danger of the poisoning is *wholly* on account of ptomaine formation after capture, why are not all or many more varieties of fish poisonous? Surely the catches are not limited to the varieties described by him as dangerous. In the second place, he particularly mentions the season 'May to October.' The period may represent the hottest portion of the year, but it may have a deeper significance, for it may be the spawning period. It is at least plausible to hold the opinion that the most favourable period for spawning would be at the hottest season. It is true that there are species of fish which decompose more rapidly than others. The Carangidae and the Scomberidae are recognized as such, but many of the members of these families, especially of the former, are excellent food-fish, and have never been known to poison. A theory which attributed fish poisoning wholly and solely to the presence of ptomaines would indeed be hard to accept, in view of the cases above mentioned.

With the single exception of the case of poisoning by the barracuda off Ponce, the writer can vouch for the accuracy of the cases he has described, having been present on some occasions, or having personally seen the other cases soon after the symptoms showed themselves. Moreover, he has no reason to doubt the authenticity of the Ponce case. Would not a purely ptomaine theory of fish poisoning be shattered by the experiment with the 'jelly' of *Lactophrys bicaudalis* on the dog? It is conceded that a certain percentage of cases of fish poisoning is due to, and results from, ptomaine formation consequent on long exposure to the sun after the capture of the fish and before its preparation for food. It is also admitted that this percentage is high. It is, however, an undeniable fact that freshly caught fish can, and do commonly produce toxic effects where no possibility of ptomaine formation exists.

Sir William Osler also recognizes the fact that fish normally produce physiological but toxic substances.

The study of the subject of poisonous fish is, therefore, an important one, and especially so in the tropics, for while it is true that cases of fish poisoning may occur in any other zone, yet in the tropics they are of much more frequent occurrence, and have not only caused serious illness, but have often resulted in death. The experience of natives is valuable in so far as it points out which fish should be entirely banned from the table, and which should be regarded with suspicion. They themselves do not refrain from eating the merely 'suspicious' class. As mentioned above, a high percentage of cases of fish poisoning may be attributable to ptomaine formation between capture and ingestion. These cases present the features of ordinary ptomaine poisoning, exhibiting a gradation of severity in proportion to the quantity ingested, the virulence of the toxin, and the natural vital resistance of the patient.

With regard to poisoning by freshly caught fish, the following observations may be made. Many cases of this nature have occurred in the period July to October: the fish remarked as being responsible for the poisoning have been chiefly Sprat, Barracuda, and Kingfish. Poisoning has also occurred from eating fish caught in certain localities. One case of this nature has been mentioned when dealing with *Clupea Thrissa* above. Some of the fisher folk moreover, although they regard the roe and liver of most fish as excellent, yet consider these parts in 'suspicious' fish as most likely to produce toxic symptoms.

We may therefore conclude: –

(a) That these fish are especially liable to be toxic in the spawning period.

(b) That they betake themselves to certain localities for this purpose.

The poison is possibly of the nature of a protective secretion which serves to protect the fish during the period in which it is engaged in the propagation of its species.

Poisoning by fish may, however, occur at all seasons of the year, and may not be simple ptomaine poisoning. It is worth while to investigate the question whether poisoning in such instances may not be due to a toxin present in the body of the living fish, a toxin which may either be a normal physiological product, or the product of the growth of bacterial organisms, themselves either normal inhabitants of the fish, or present in its body from disease, or caused by the feeding of the fish in highly polluted waters.

We know that mussel poisoning is due to the toxin $C_6 H_{15} NO_2$ present in the body of the living fish. This toxin has been isolated by Brieger, and termed mytilotoxin. Jorgen Thesen (*British Medical Journal*, Vol. II, 1902, p. 33) found that mussels in the harbour of Christiana, Norway, were poisonous in June, and although the poisonous symptoms were in ratio to the contamination of the water in which they flourished, and although extracts were obtained from them, producing symptoms similar to those

produced by strychnine or by curare, yet he could find no specific bacterium in the fish. It may be possible that the toxin may be a true endo-toxin present in the bacterial cell during its life, but not capable of being disseminated through the fish until after the death of the bacterium, when the containing cell is broken up and disintegrated.

Again, in cases of food poisoning, we often find the *Bacillus enteriditis* or Gartner's Bacillus. Investigation of this organism by various authorities shows amongst other features :—

(a) That it has been found in the duodenum of a healthy man, and in the intestine of a healthy goat in polluted drinking waters, in oysters from polluted beds, and in other shellfish in polluted waters.

(b) That it produces an endo-toxin which is of a very resistant character, neither cooking, smoking nor pickling impairing its virulency.

(c) That it produces gastro-intestinal symptoms. May there not be in the living fish a bacillus of this nature?

The symptoms of fish poisoning may be divided into two classes. These groups of symptoms may be distinct and occur primarily and independently of one another, or the second group may follow on the first.

FIRST GROUP.

The first group of symptoms are mainly those of an acute gastro-enteritis, of an acute gastro-intestinal irritation. There is at first a feeling of lassitude followed by nausea and vomiting and accompanied by diarrhœa with severe cramp-like pains in the abdomen. The stools are loose, copious and foul-smelling; the pulse is rapid, weak, and collapsible; the respirations are increased in rate, and may be difficult; the temperature is subnormal; the extremities cold, and the body covered with sweat. The picture is one of general collapse. These symptoms may begin in from four to ten hours after the ingestion of the fish, and, of course, they vary in intensity with the amount of toxin taken, and the constitutional condition of the patient. In cases where vomiting starts early, a better result is often sooner observed, as the act of vomiting throws out a portion of the toxin which would otherwise be absorbed. If seen on the first day, and treatment of an eliminative type be instituted, it is generally found that in the subsequent twenty-four hours the condition is somewhat better. The character of the pulse and of the respiration is more nearly normal, and the temperature may be normal or slightly elevated (100 or 101 degrees). The vomiting has usually ceased, and there is little or no nausea. The general appearance of the patient has improved, and he no longer exhibits symptoms of collapse, although he is very weak. He may, however, complain of headache and drowsiness, of a burning and tingling sensation in the skin, of formication. His eyes may burn and run water when he looks at a bright light. He may complain of scalding on micturition. In the majority of cases the condition clears up in a week to ten days. Often the irritation of the eyes by light, and the formication persist for a few weeks, and, of course, the physical weakness is only gradually overcome.

SECOND GROUP.

The second group of symptoms may follow on the first when prompt treatment has been neglected, or may occur independently. They seem to indicate the presence of a poison having a specific action on the nervous system. The symptoms are slow in making their appearance; in many cases, beyond mere malaise, no definite symptom may appear until four to six days have passed. They are correspondingly slow in disappearing, months often elapsing before complete recovery takes place. These cases are characterized by a feeling of lassitude usually, without nausea and vomiting; constipation is often the rule; there is no fever; the pulse rate may be slightly accelerated; the respiration rate is normal; there is very persistent headache; there is formication and a tingling sensation of the skin, with burning of the eyes when a bright light is looked at. But one of the characteristic features of this type is the pain in the joints and bones, often excruciating, and occurring more frequently in the hips, knees, and the vertebral column. This symptom-complex seems to be due, as was stated, to a toxin singling out for its attack the nervous system. Although this group does often follow on cases of the first group, yet it is not always to be ascribed to deferred initial treatment, for there may be a mixed toxin productive of the symptoms peculiar to both groups.

It may be again noted that the symptoms of poisoning resulting from the ingestion of *Lactophrys bicaudalis* resemble those produced by alcoholic intoxication.

As regards the treatment of fish poisoning, it may be stated, to begin with, that the treatment of the cases of the first group is more satisfactory and productive of good results, than the treatment of cases of the second group.

In the gastro-intestinal cases the source of the trouble must be removed as early as possible. Early evacuation of the stomach contents must be procured; the stomach must be washed out, and a brisk purgation set up. We have many purgatives to choose from, but the best in these cases are the salines, and the best saline is Epsom salts, of which the writer gives 1 oz. If the stomach is being washed out the solution of magnesium sulphate can be left in the stomach after the lavage before the tube is withdrawn, thus preventing the possibility of its taste causing vomiting, which will throw it off. Maintenance of the bodily heat by hot-water bottles or any other means is also indicated. Having eliminated the poison by all possible means, our next effort should be directed towards the improvement of the condition brought about by the amount that has been already absorbed. Stimulants, administered hypodermically or per rectum, if vomiting exists, are useful. In cases where they can be administered by the mouth give whisky or brandy. Tonics are used in restoring the patient's health after the attack. It has been stated that the juice of fresh limes is a useful antidote.

The second symptom-complex is less amenable to treatment. Of course, as in the first group, the elimination of the toxin is indicated, but one has not here the comparatively easy task of eliminating it from the intestine, as it is already absorbed. A

saline purgative should be given. Osler recommends hypodermic saline infusions for the promotion of toxin-elimination. Iodide of potassium and the bromides, arsenic and tonic treatment have been found useful.

As cases of fish poisoning are of very common occurrence in the British Virgin Islands, it will not be out of place to mention certain plants growing locally that are used as remedies, and indeed given in the majority of cases before the physician is consulted.

The following are very commonly used :—

CONOCARPUS ERECTUS.

This is a plant belonging to the Combretaceae. It is locally called 'button wood bush'. It is noted by Sir Francis Watts in his *Nature Teaching* as 'West Indian alder', 'button tree', 'Zaragoza mangrove'. It is a small tree, often found associated with other mangroves such as the 'red mangrove' (*Rhizophora Mangle*), and the white mangrove (*Laguncularia racemosa*). While Grisebach describes it as being common in mangrove swamps, W. G. Fishlock states that in these islands it is more frequent in drier places, e.g. on rocky cliffs near the sea-shore. The plant is rich in tannic acid, and thus possesses highly astringent properties.

HYPTIS CAPITATA.*

This is a plant belonging to the Labiatae. It is locally known as 'Lord Lavington' and 'rabbit weed'. Plants of this order are noted for their volatile oils and possess carminative properties.

Both of the above plants are used by the natives of the British Virgin Islands as antidotes for fish poisoning. They are prepared similarly. Their leaves are boiled with molasses or with sugar, and made into a tea. It is said also that the berries of the Conocarpus are roasted, and the infusion used. The results obtained are, it is reported, very satisfactory, particularly from *Conocarpus erectus.*

PASSIFLORA FOETIDA.

This plant is locally termed 'running pop' or 'love-in-a-mist'. It is often used in cases of fish poisoning, especially in the island of Anegada. Its leafy parts are used, boiled as a tea, either by themselves or in conjunction with the leaves of *Conocarpus erectus.*

Fish that are universally recognized as poisonous need never cause anxiety, for they are never placed on the market. Fish, however, that have merely a bad reputation are the ones which are to be feared. Their sale cannot rightly be prohibited, but the consumer should be guided as regards their fitness for consumption.

*The plant, known in Antigua as 'Lord Lavington', and in St. Croix as 'rabbit weed' and in Barbados as 'hops' is not *Hyptis captitata*, but the nearly related and much more commonly distributed species. *Leonotis nepetaefolia*—Ed. *W.I.B.*

With regard to these fish, the following rules are worth observing:—

(a) Avoid all Cavallies, especially the 'Horse eye' Cavally (*Caranx latus*).

(b) See that all fish is fresh. A fresh fish should have bright red gills, unsunken eyes, and should sink when placed in water.

(c) Avoid the liver and the roe. Remove them from the fish as soon as possible, to prevent any chance of absorption of a possibly present poisonous secretion. Clean the fish thoroughly with freshly squeezed lime juice.

(d) Do not eat the Guinea bird Shellfish. If you do, remove the jelly.

The writer has endeavoured in the preceding pages to give his observations on fish poisoning as observed in the British Virgin Islands. He is indebted to Mr. W. C. Fishlock, Curator of the Agricultural Experiment Station, Tortola, for his interest and valuable assistance in the identification and description of the plants which are locally used as antidotes, specimens of which were obtained from those who had experienced fish poisoning, and found the use of the plants beneficial.

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MANURIAL EXPERIMENTS WITH SEA ISLAND COTTON IN ST. VINCENT IN 1917-18.

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INTRODUCTION.

In a previous paper by the present writer [1], a general account was given of the manurial experiments with Sea Island cotton which had been carried on at the St. Vincent Experiment Station during the period 1912-16. A more detailed account was given of the results obtained in the season 1916-17, the aim of the work in that season being to discover how the yield of cotton was built up from day to day, and thence to discover the cause of the low yield per acre usually obtained in St. Vincent.

In this investigation the methods of study originally perfected by Dr. Lawrence Balls in his work on Egyptian Cotton were largely made use of. The number of flowers opening daily in every plot of the Manurial Series was recorded for a period of five and a half months. The number of bolls opening daily in every plot of the Manurial Series was recorded daily for a period of fifty-three days. After that pickings were made at intervals of five days. A daily examination was made of some thirty plants, and as far as possible, an accurate record kept of the fate of every bud, flower, and boll produced. This intensive examination made it possible to trace in a very precise way the effect of environmental conditions on the plants.

The conclusions which were arrived at from a study of the Manurial Experiments in 1916-17 may be summarized briefly as follows :—

1. The percentage of flowers maturing into bolls did not vary greatly in the different plots, and it would be unsafe to assume that such variations as did occur were the result of any difference in manurial treatment.

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1 'Manurial Experiments with Sea Island Cotton in St. Vincent'. *West Indian Bulletin*, Vol. XVI, No. 3.

2. All the manured plots showed an increased yield over the unmanured, the increase being no less than 116 per cent. in the case of the plots receiving a complete manure consisting of artificials and cotton-seed meal.

3. The element most necessary under the soil conditions prevailing in St. Vincent is potassium, an application of sulphate of potash producing an increase of 76 per cent. over the unmanured plots.

4. The chief cause of the low yield of cotton in St. Vincent was shown to be due to the shedding of buds and bolls consequent on very heavy rainfall, and complicated and intensified by cryptogamic disease. It was made clear that the cotton stainer was responsible for a great deal of the shedding of almost full-grown bolls, and that where cotton stainers were abundant, the yield was in the neighbourhood of zero.

Objects of the Investigation in 1917-18.

During the season 1917-18, the study of the Manurial Experiments was continued. The aims of the investigation were as follows:—

1. To see if the general conclusions arrived at respecting the effect of different manures on the yield would receive confirmation under a different set of environmental conditions.

2. To verify the conclusion stated above, that differences in manurial treatment cause no significant differences in the proportion of flowers which mature into bolls.

3. To study the differences induced in the form of the flowering and bolling curves by the differences in weather conditions, etc., in two successive seasons.

4. By growing alternate rows with two plants per hole instead of one, to obtain an idea of the effect on yield of the two plants per hole method of planting.

A few slight modifications were introduced into the methods of study.

Both flowering and bolling records were kept of all rows, the number of flowers being counted daily except Sunday, and the number of bolls weekly. The number of flowers for the Sunday was taken as the arithmetic mean of the preceding and succeeding days. Two of the rows in each plot were sprayed with Burgundy mixture, with the object of seeing whether by this means the external boll disease could be controlled. As the results of this experiment were largely negative, and as all the plots were treated in exactly the same way, the validity of the general conclusions arrived at by a study of the flowering and bolling curves need not be questioned.

In all other respects the methods of cultivation and treatment of the plots were similar to those of 1916-17, for which the reader is referred to the writer's former paper.

In Table I. will be found the results of the number of flowers and bolls produced by each of the manurial plots in 1917-18, the percentage of bolls to flowers, the yield of each plot in ℔. per acre,

and the increase or decrease of each combination of manures over the no-manure plots.

TABLE I.

RESULTS FROM THE MANURIAL EXPERIMENTS IN 1917-18.

Name.	Plot.	No. of flowers.	No. of bolls.	Per cent. bolls to flowers.	Average.	Yield in lb. per acre.	Average.	Difference on No manure. N.M = 100.
								Per cent.
No manure	1 a	4,234	2,087	49·3		459		
	1 b	5 688	2,401	42·2	44·8	528	482	–
	1 c	4 875	2,087	42·8		459		
Nitrogen	2 a	3,455	1,257	36·4		276		
	2 b	6,758	2,855	42·3	42·5	627	551	+ 14
	2 c	7,010	3,412	48·7		750		
Phosphate	3 a	4,358	1,511	34·7		332		
	3 b	7,156	3,498	48·9	45·5	769	634	+ 32
	3 c	6,895	3,640	52 8		800		
Potash	4 a	8,336	4,077	48·9		896		
	4 b	9,071	4,843	53·4	55·0	1,064	1,040	+ 116
	4 c	8,407	5,282	62·8		1,161		
Phosphate and potash	5 a	6,825	3,240	47·5		712		
	5 b	8,139	4,421	54 3	50·7	972	819	+ 70
	5 c	6,983	3,512	50·3		772		
Nitrogen, phosphate and potash	6 a	7,054	2,757	39 1		606		
	6 b	9,999	4,971	49·7	48·7	1,093	864	+ 79
	6 c	8,601	4,058	47·2		892		
Cotton-seed meal	7 a	6,370	2,410	37·8		530		
	7 b	7,148	3.319	46·4	45·4	729	721	+ 50
	7 c	7,891	4,107	52·0		903		
Cotton seed meal, phosphate and potash	8 a	10,579	5,132	48·5		1,128		
	8 b	8,513	3,98	46·8	48·9	875	1,006	+109
	8 c	9,023	4,625	51 3		1,016		

The main conclusions arrived at may be summarized as follows :—

1. All the manured plots show an increase over the unmanured ; the largest increase is shown by No. 4, the potash plots, which gave 116 per cent. more seed-cotton than the no-manure plots.

2. Last year's conclusion that potassium is the element most necessary under the soil conditions of St. Vincent is confirmed. It was pointed out that the physiological affection known as 'rust' results from a deficiency of potash in the soil. In 1917-18 'rust' appeared in every plot of the manurial series. The no-manure, nitrogen, phosphate, and cotton-seed meal plots were the most severely attacked.

3. An application of potash alone is more beneficial than a combination of potash and phosphate. This striking observation was previously made in 1916-17, and it is interesting to see it confirmed by another season's work. The present writer is unable to suggest any reason for this phenomenon.

It has been pointed out that an application of cotton-seed meal at the rate of 600 lb. per acre is insufficient to meet the nutritive requirements of the plants when grown on the same land for a number of years. In the light of the results of these manurial experiments it is expedient to warn planters that the characteristic signs of potash deficiency are very apparent on many estates in the island, and it may be predicted with certainty, that if there is a continuance of the present system of cultivation, which insists on the burning of old cotton plants at the end of the season, and at the same time often makes no provision for restoring the fertility of the soil, the land will in many cases become so poor that cotton growing will become unremunerative. The effects of poor nutrition are made manifest not only by the presence of 'rust', but also by the stunted appearance of the plants, which succumb very easily to 'black arm', and are rapidly killed if attacked by black scale (*Saissetia nigra*, Nietn.). It is not apparent that defective nutrition causes the plants to be more susceptible to these affections. Healthy, well nourished plants seem to be attacked in just the same degree, but recover more quickly from the above-mentioned diseases, while if attacked by black scale, the plants do not suffer to the same extent as those which are poorly nourished.

COMPARISON OF THE CONDITIONS UNDER WHICH THE CROPS WERE GROWN IN 1916-17 AND 1917-18.

In 1916-17 the history of the crop in brief was that, planted on July 7, very heavy rains fell during most of October and November—the most critical period of the growing season. Consequently, the external boll disease and the soft rot due to *Phytophthora* sp. did much damage; and in addition, there was a large amount of shedding both of buds and bolls. Cotton stainers were present throughout the season, and caused great loss of crop by spreading the fungi of internal boll disease. Bolls affected by this disease were more easily shed than healthy bolls. The percentage of bolls to flowers from the first part of the flowering curve was under 20 per cent. All the flowers from the second part of the flowering curve were lost owing to cotton stainers, which during the month of January became so abundant as to cause every boll in the field to become diseased.

The history of the conditions during the season 1917-18 forms a great contrast to the above. Planted on August 8, very favourable weather conditions were experienced almost throughout the season.

A comparison of the rainfall of the two seasons is shown below.

Rainfall of season 1916-17, in inches.			Rainfall of season 1917-18, in inches.		
July 1916.	...	8·69	July 1917.	...	16·13
Aug. „	...	13·80	Aug. „	...	10·69
Sept. „	...	8·31	Sept. „	...	9·48
Oct. „	...	17·77	Oct. „	...	10·33
Nov. „	...	29·82	Nov. „	...	5·39
Dec. „	...	2·07	Dec. „	...	4·66
Jan. 1917.	...	7·57	Jan. 1918.	...	6·43
Feb. „	...	3·85	Feb. „	...	5·94

The chief feature in the rainfall of the two years is the extraordinarily heavy rainfall of October and November 1916. The weather in the corresponding months of 1917 was exceptionally favourable for cotton.

A remarkable contrast is also presented, if a comparison be made of the prevalence of stainers in the two seasons. During both seasons collections of as many stainers as possible were made daily from the time when they were first seen. The numbers collected during the two seasons are shown below.

1916-17. Number of stainers collected. Month ending			1917-18. Number of stainers collected. Month ending		
July 31	...	2,696	July 31	...	0
Aug. 31	...	13,554	Aug. 31	...	0
Sept. 30	...	6,181	Sept. 30	...	0
Oct. 31	...	896	Oct. 31	...	0
Nov. 30	...	1,028	Nov. 30	...	0
Dec. 31	...	16,015	Dec. 31	...	25
Jan. 31	...	164,609	Jan. 31	...	0
Feb. 28	...	No collection	Feb. 28	...	11,511

The numbers collected give a fair idea of the abundance of the insect. In the past season the first stainer appeared at the Experiment Station on December 3, but it was not until the beginning of February, when picking was practically over for the seas n, that flights of stainers began to come in from neighbouring estates. Briefly it may be said that in 1917-18 the loss from stainers at the Experiment Station was nil. Instead of only 17·2 per cent. of the bolls maturing, almost 48·2 per cent. matured, and the percentage of stained cotton was negligible. How much of the increase is due to favourable weather conditions and how much to the absence of stainers we have no means of judging, but it is clear that no small part of the increase is due to the latter factor.

The question has now to be considered whether different manures have any effect on the number of flowers which mature into bolls. From last year's results it was concluded that, on the whole, there was little evidence that the percentage of bolls to flowers was influenced in any way by different manures.

This conclusion now requires some modification. It will be seen that plot 3a has given the lowest percentage of bolls to flowers in both seasons, and that in both seasons the manure producing the highest yield (No. 8 in 1916-17 and No. 4 in 1917-18) has given the highest percentage of bolls to flowers. Plot 3a is so far below 3b and 3c that one is driven to the conclusion that some other factor is operative in the plot; possibly there is some special condition of soil present. It is obvious that in plots receiving the same treatment there is considerable variation in the percentage of bolls to flowers—a variation which is probably due partly to chance and partly to different soil conditions. If the results of each season be brought to a common standard by taking the mean of each set of three plots as 100, we find that in 1916 17 the probable error of a single result is $\pm 7{\cdot}4$ per cent., and in 1917-18 $\pm 7{\cdot}2$ per cent. Combining the results of the two seasons we obtain $\pm 7{\cdot}2$ per cent. as the standard for practical use in plots $\frac{1}{40}$-acre in area. It will be necessary to bear this figure in mind when experiments are instituted involving a comparison of different varieties in respect of shedding.

The correlation was worked out between the yield in lb. per acre, and the percentage of bolls to flowers. A positive correlation of $r = {\cdot}72 \pm {\cdot}09$ was obtained. Hence we may conclude that under the same weather conditions the factors which are favourable to high yield are also favourable to a high percentage of bolls to flowers. Part of the explanation of this correlation no doubt lies in the fact already mentioned, that in poorly nourished plots plants are liable to be killed by fungoid disease or by black scale. If any plant thus killed bore any fruits, its loss would bear directly on the percentage of bolls to flowers of that particular plot. Although at the end of the season no definite counts were made of the number of plants remaining alive in each plot, it was recorded that more than 20 per cent. of the plants died in the no-manure and nitrogen plots, while none died in the potash and complete manure plots.

On the evidence from the past season, we may state that it is not apparent that manures have a direct action upon the percentage of bolls to flowers, but that plots adequately manured are

likely to produce the maximum number of bolls possible under the prevailing set of weather conditions. In addition, the cause of abnormally small percentages of bolls to flowers in certain plots—adjacent plots showing a high percentage—would seem to lie partly in the mechanical condition of the soil, and partly in a reduction of the number of plants—reduction due to the interaction of the nutrition and disease factors.

THE FLOWERING AND BOLLING CURVES OF 1917-18.

In Plate 1 are shown the flowering and bolling curves of the eight manurial combinations. Several important points are brought out by these curves, but in order that their import may be adequately appreciated, a comparison has been made in Plate 2 of the flowering and bolling curves of 1917-18 with those of the previous season. A study of these curves leads to the following conclusions:—

1. Flowering commenced in both seasons in the tenth week from sowing. The graphs do not indicate any lower values than ·025 per plant per day, but as a matter of fact flowering commenced in both seasons on the 57th day from sowing, and some fourteen days elapsed before the number of flowers per plant was large enough to indicate on the graphs.

2. From this point the rate of flowering increased rapidly, rising to a maximum in the sixteenth week after sowing. The rate of increase was fairly regular in 1917-18, but less regular in 1916-17.

3. After this the curves both descend again fairly regularly in 1917-18, less regularly in 1916-17. The lowest point of both curves is reached in the 22nd week after sowing.

4. In 1916-17 the flowering curve again rises, reaches a second maximum, then drops rapidly almost to zero. In 1917-18 the flowering curve does not again rise. The explanation of this striking difference is a simple one. In 1916-17 the weather after November was favourable to vegetative growth, and thus a second set of flowers was produced on monopodia springing from the lower part of the main stem. In 1917-18 the months of November and December were comparatively dry months, and while the weather was favourable for the maturing of the bolls from the first part of the flowering curve, it was unfavourable for vegetative growth, and the monopodia produced very few flowers

5. The amplitude of the flowering curve is greater in 1917-18 than in 1916-17. The difference is ascribed mainly to the almost entire absence of bud-shedding in the early part of the former season. The greater regularity of the 1917-18 curve can also be put down to the same cause.

6. The reason for the increased yield of 1917-18 is well brought out by the curves on Plate 2. The greater amplitude of the bolling curve of 1917-18 indicates that the chief factor concerned in the increase lies in the absence of (a) shedding conditions, (b) fungoid disease. The flowering curve of 1917-18 rises higher than that of the preceding season, but not so much higher as to give any pronounced indication that this increase

in height constitutes more than a lesser factor in the increased yield.

7. The bolling curves in Plate 1 present some rather peculiar features, the full bearing of which are as yet not entirely understood. In the first place, the flowering curves seem to be divided into two distinct sets: (a) plots 1, 2, and 3; (b) plots 4, 5, 6, 7, and 8. The modes of the latter set are much higher than those of the former. After what has been said respecting the function of potash in the nutrition of the Sea Island cotton plant, it is easy to connect the high modes of set (b) with the fact that they are all supplied with potash in some form, while those of set (a) receive none. In the mean curves of flowering and bolling of Plate 2 we see that the bolling curves reach their maximum seven weeks after the maximum of the flowering curves. This is due to the mean maturation period of the Sea Island boll being about fifty-one days. A study of the bolling curves of Plate 1 shows that three plots, Nos. 8, 7, and 6 reach their maximum not seven weeks, but six weeks after the maximum of the flowering curves. The difference in the amplitude of the flowering curves in the 15th and 16th weeks after sowing is not great, and if the shedding of the bolls of the 16th week was somewhat greater than that of bolls produced in the preceding week, the mode of the bolling curve would fall a week earlier. It is not easy to see, however, why the same effect should not be shown by the potash curve, and this is a strong reason why the explanation given above should be considered only as a partial one. The mean maturation period of the Sea Island boll being fifty-one days, the flowers produced in the week ending December 21 should mature during the week ending February 8. Actually, however, the number of flowers of the week ending December 21 is less than the number of bolls maturing in the week ending February 8. This can be accounted for either on the assumption that the maturing period of the boll lengthens somewhat at the latter end of the season, or that our records were inaccurate. After careful investigation it was decided that the latter explanation was not applicable, while we have very little evidence bearing on the point as to whether a lengthening of the maturing period of the boll occurs at the latter end of the season. For the present it is sufficient to record the fact and to state that, such a length of the maturing period may not be improbable in old and weakened plants.

The Effect on Yield of the Two Plants per Hole Method of Planting.

It has already been stated that alternate rows of the plots had two plants per hole instead of the usual one. Plate 3 shows the flowering and bolling curves of the two spacings. A study of these curves enables us to arrive at the following conclusions:—

(1) Flowering in both spacings begins at approximately the same time. The rate of increase of flowering of the denser spacing is much greater, taking flowers per square yard per day as the standard for comparison. The period at which flowering is at a maximum is the same in both spacings, though the curve of the denser spacing reach the higher level. From the week ending November 23 onward, the rate of flowering in both rapidly

declines, but the denser spacing does not lose its superiority till three weeks after this. At this time both sets are flowering at about the same rate.

(2) Flowering ends in both sets at practically the same time. In neither spacing is a second set of flowers produced.

(3) In regard to the bolling curves, it will be seen that the length of the period over which the crop was produced is nearly the same for both spacings, the denser set giving curves of greater amplitude. Bolling in both spacings ends at the same time.

(4) It would not be wise to conclude from the above statements that the superiority of the denser system of spacing the plants is unworthy of further investigation. The results obtained hold only for one season, and are true only for the particular set of conditions under which the plants were grown. The results, however, do indicate that it is advisable to reopen the question as to which is the best spacing to adopt for Sea Island cotton.

The table below shows the main points of difference in the results obtained from the two systems of planting.

Table II.

RESULTS OBTAINED FROM THE TWO SPACINGS 5 FEET BY 2 FEET, 1 PLANT PER HOLE, AND 5 FEET BY 2 FEET, 2 PLANTS PER HOLE.

Series.	Plants per hole.	Area in acres.	No. of flowers.	No. of bolls.	Per cent. bolls to flowers.	Average.	Flowers per plant.	Bolls per plant.	Flowers per sq. yd.	Bolls per sq. yd.
1	1	$\frac{7}{65}$	25,178	11,013	43·7	..	56·2	24·2	50·6	22·1
2	1	$\frac{7}{65}$	27,487	14,950	54·4	50·8	61·4	33·4	55·2	30·0
3	1	$\frac{7}{65}$	28,120	15,297	54·4	...	62·8	34·1	56·5	30·7
1	2	$\frac{6}{65}$	27,406	12,059	44·0	...	35·7	15·7	64·2	28·3
2	2	$\frac{6}{65}$	32,602	16,419	50·4	48·3	42·5	21·4	76·4	38·5
3	2	$\frac{6}{65}$	31,569	15,974	50·6	...	41·1	20·8	74·0	37·4

Table II enables us to arrive at the following conclusions :—

1. The number of flowers and bolls per square yard is greater in the two plants per hole system. The superiority of the denser spacing in regard to the number of bolls per square yard amounts to 26 per cent. This superiority seems too great to be the result of chance alone, and gives encouragement for further experiment.

2. The number of flowers and bolls per plant is greater in the one plant per hole system.

3. In regard to the percentage of bolls to flowers, there is very little difference in the results obtained in the two spacings, and it cannot be maintained that with the increase in density of population, there has been any marked reduction in percentage.

Perhaps the most complete study of the question of the effect of spacing on the yield of cotton has been carried out by Messrs. Balls and Holton[2]. They showed that spacing did not affect shedding. It is the universal practice in Egypt to leave two plants standing together. Their conclusion in regard to this custom is as follows: 'The habit is not a mere insurance against possible damage to the plant, but in all circumstances it gives about 10 per cent. higher yield, since each of the pair produces a little more than half the crop which a single plant would give, and not one-half exactly.'

SUMMARY AND DISCUSSION.

The manurial experiments with Sea Island cotton at the St. Vincent Experiment Station have been studied by means of flowering and bolling records for two successive seasons, in which weather conditions were widely different.

All the manured plots showed increases over the unmanured. The increase was greatest in the plot to which potash was applied; but a large gain was also shown by the complete manure plots. The remarkable fact was brought out that the addition of phosphate to the potash tended to lower the yield.

Manures had no effect whatever on the time of maturing of the crop. Manures had no effect on the percentage of bolls to flowers. The yield obtained when two plants per hole were left was considerably greater than when there was only one. The need for further experiments on the spacing of Sea Island cotton is emphasized. Spacing had no effect on the percentage of bolls to flowers.

It has been shown clearly that, under the conditions under which the experiments were carried out, there is a striking uniformity in the time at which flowering begins, reaches its maximum, and declines to zero. If the sowing date be known, we can state with certainty when most flowers and bolls will be produced, and when the crop will be finished. We cannot predict what the size of the crop will be further than by stating its probable maximum. The size of the crop depends on weather conditions, and on the incidence of fungoid disease. Thus, in the West Indies, or indeed in any country where cotton depends for its water-supply on rainfall and not on irrigation, the value of flowering records is very much less than in Egypt. The Egyptian bolling curve is of less amplitude than the flowering curve, chiefly through shedding. The percentage of shedding is said to be practically constant at 40 per cent. In non-irrigated countries

2. 'Analyses of Agricultural Yield. Part 1: The Spacing Experiment with Egyptian Cotton, 1912', by W. Lawrence Balls and Francis S. Holton. *Phil Trans. Roy. Soc.*, Ser. B., Vol. 206, Pp. 103-80.

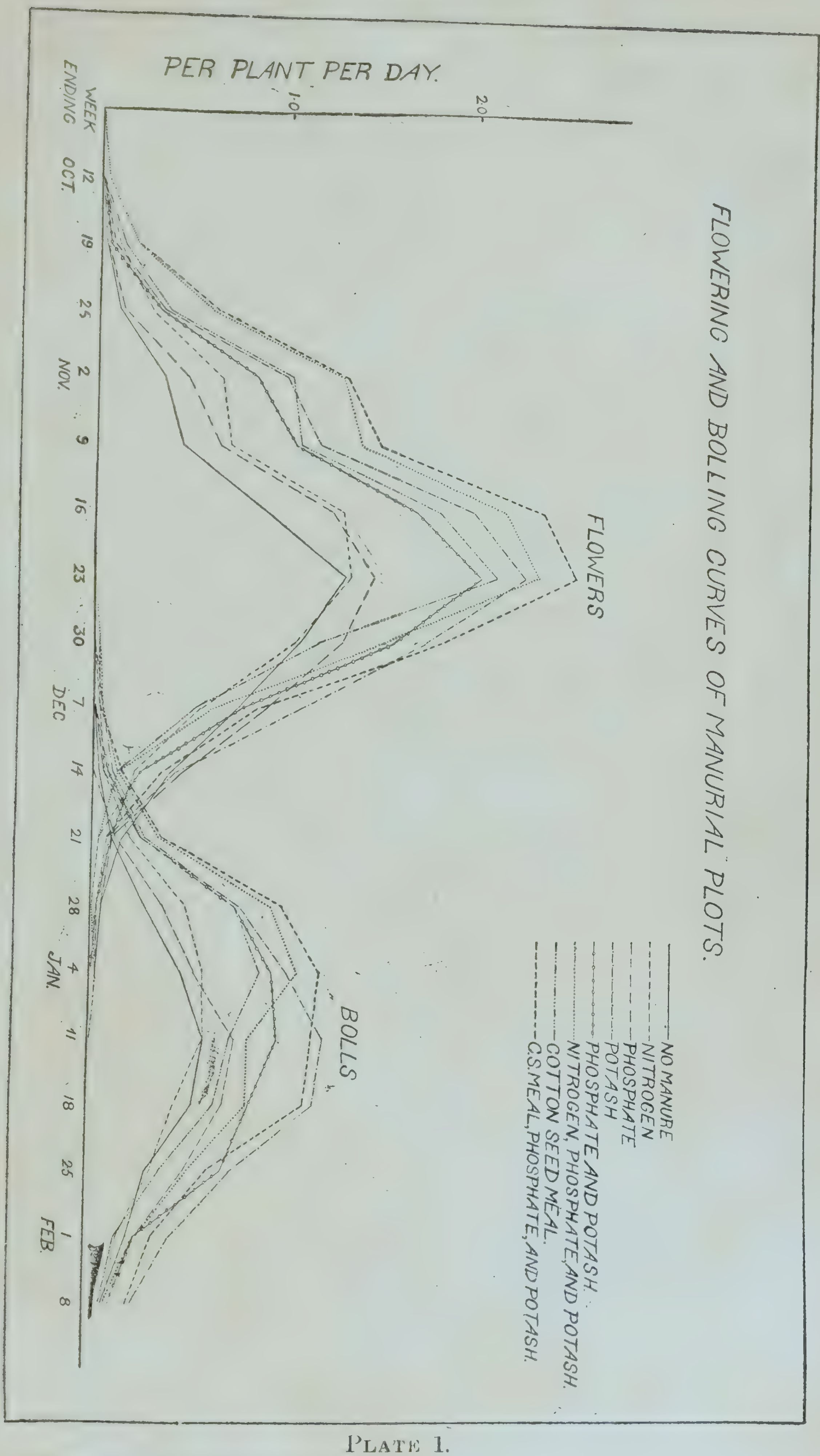


PLATE 1.
Flowering and bolling curves of the eight manurial combinations.

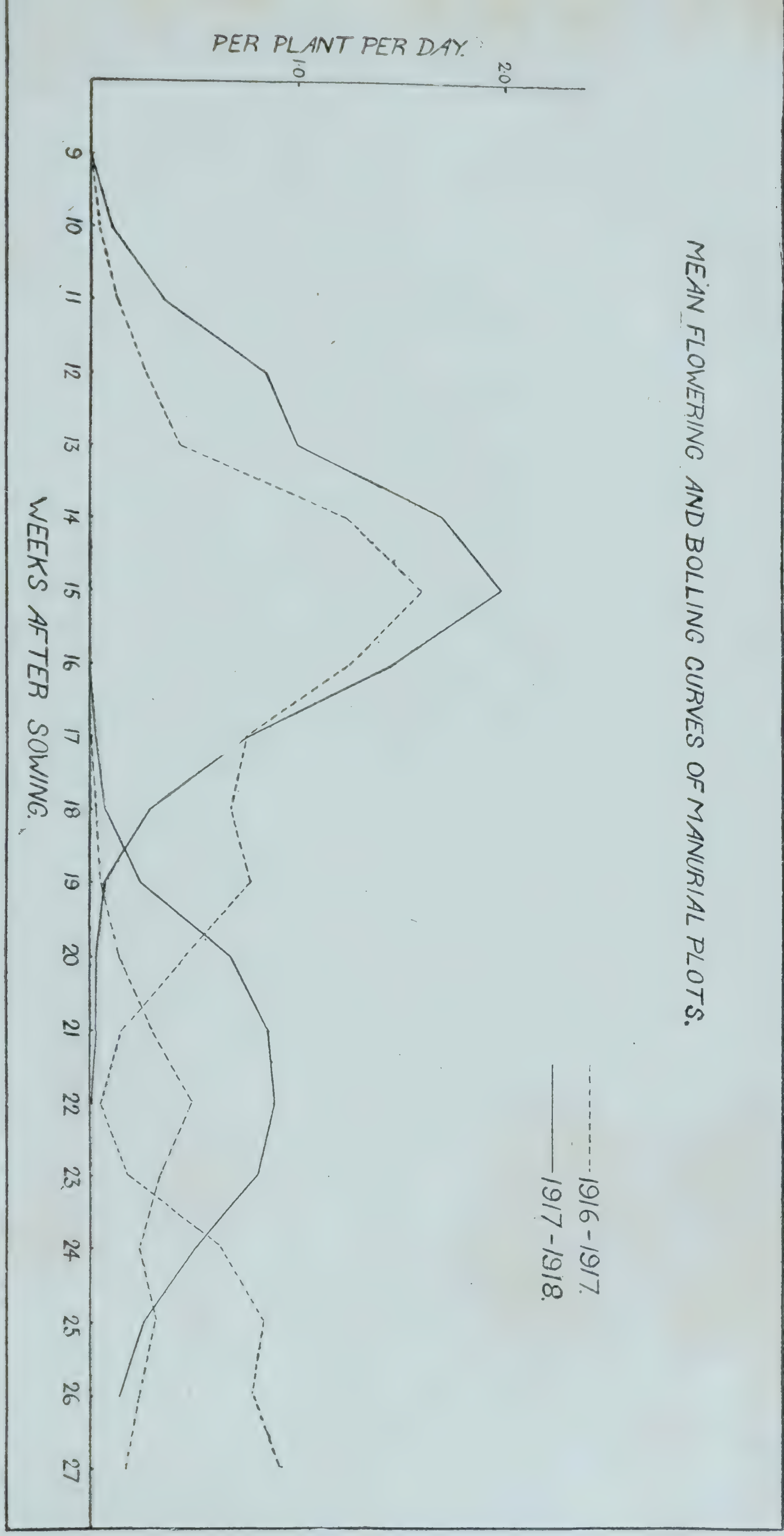


PLATE 2.
Comparison of flowering and bolling curves of 1917-18 with those of the previous season.

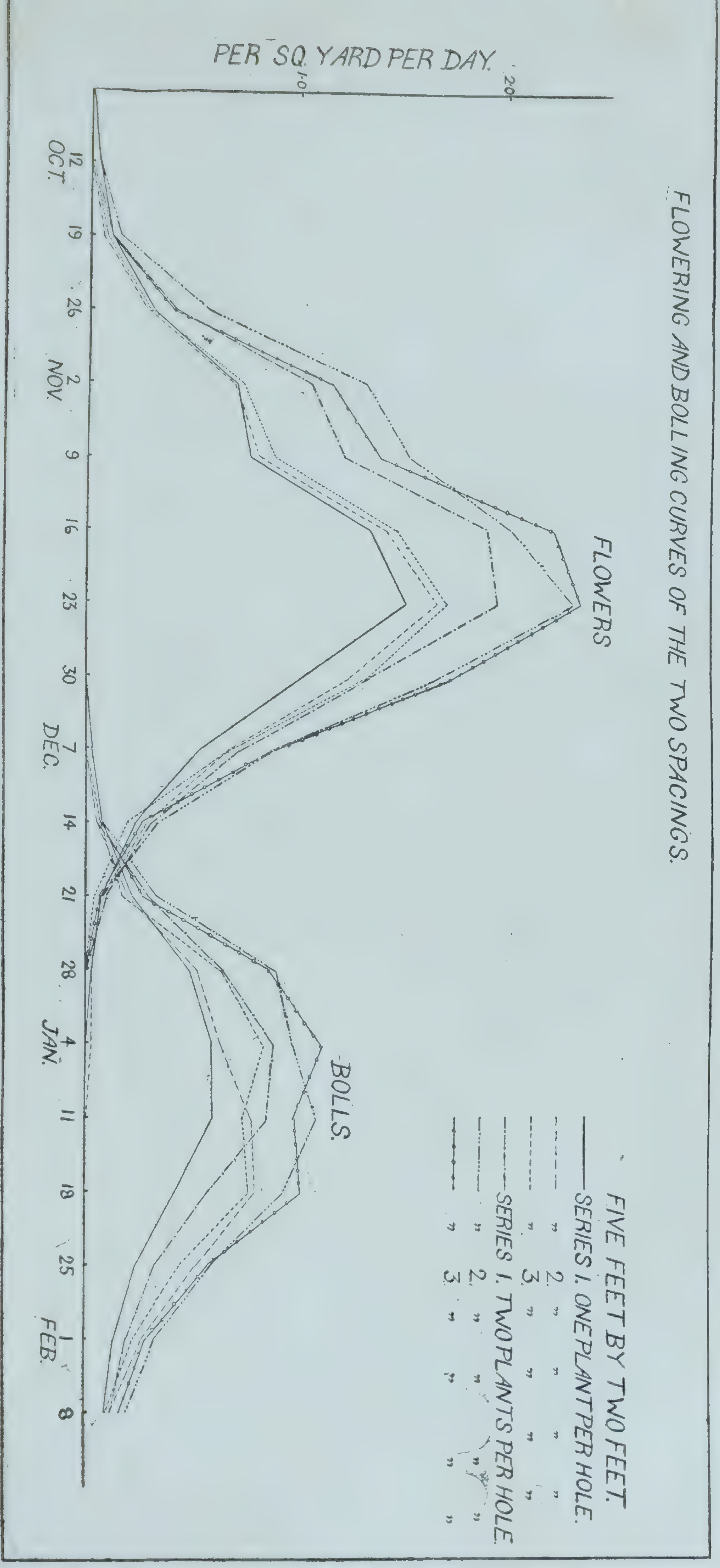


PLATE 3.
Flowering and bolling curves of the two spacings.

the bolling curve represents the bolls left after shedding and disease have taken their toll, and we have seen that the percentage of bolls to flowers fluctuates greatly from season to season. For manurial and spacing experiments in the West Indies, it is probably sufficient to take bolling records only, at weekly intervals. I do not think that the practical planter need concern himself with either flowering or bolling curves. For the comparison of different varieties in regard to yielding capacity, both flowering and bolling records are almost essential. It is certain that considerable differences exist in Sea Island cotton in respect of the liability to shed bolls. These differences could be brought out adequately, only by a careful study of the flowering and bolling records.

SOME OBSERVATIONS ON THE RELATION OF LINT LENGTH TO RAINFALL.

BY

R. E. KELSICK, Acting Chemical Assistant, St. Kitts.

During the season 1917-18, it was observed that the lint from the selected plants of the different strains of Sea Island cotton grown at the Experiment Station, La Guérite, was much shorter than lint from the same strains grown during the previous season.

The figures for the two seasons are given below :—

	1916-17.	1917-18.	Difference.
No. 208	55·4 mm.	52·1 mm.	3·3 mm.
No. 342	59·2	57·4	1·8
No. 416	57·2	49·5	7·7
No. 205	60·1	51·9	8·2
No. 206	58·7	52·0	6·7
No. 325	59·1	54·5	4·6

It will be seen that in every case the lint from the different strains was decidedly shorter in 1917 than in 1916. An average sample of lint from each strain in 1917 was sent to Mr. Harland, Assistant for Cotton Research to the Imperial Department of Agriculture, who commented on the poor lint length of the different strains, and suggested that deterioration might be taking place. As it was considered improbable that the plants had deteriorated, an attempt has been made to discover some other factor which could account for the difference in lint length in 1916 and 1917.

It has been found in Egypt that there is a rise in lint length a few days after the plants have been irrigated. There seems to be no reason why the same should not hold good in these islands, that is, that cotton plants will only produce lint of maximum length when they have an ample supply of water at their disposal.

A very striking difference is seen between the rainfall in St. Kitts from May to December 1916, and the rainfall for the same period in 1917. During this period in 1916 the rainfall was 56 inches, in 1917 it was only 31 inches. These figures show that the water-supply in 1917 was entirely different from what it was in 1916, being nearly twice as much in the latter year.

In order to try and obtain information concerning the effect of the rainfall on the length of the lint, the lint length of bolls maturing from dated flowers was determined.

The following average figures were obtained :—

Date of opening of bolls.	Lint length.
September 13, 1917.	49 mm.
„ 18 „	52 „
„ 23 „	49 „
„ 28 „	53 „
October 3 „	54 „
„ 9 „	55 „
„ 13 „	57 „
„ 18 „	57 „
„ 23 „	56 „

The length given on any date is the average of the length of lint of bolls opening on that date and the four previous days.

From these figures it will be seen, for example, that bolls opening on October 13 have lint 8 mm. longer than bolls opening on September 13.

The daily rainfall of the first twenty-four days of the history of bolls opening on different dates of 1917 is given in tabular form on the next page.

The differences in environment of bolls opening on different dates can now be examined, that is, the differences in the water-supply of the plant. In these islands the rainfall is generally the main factor contributing to environmental differences. Compare, for example, bolls opening from September 9 to 13, and bolls opening from October 9 to 13. Bolls which opened on September 9 to 13 were formed from flowers which opened fifty-one days before, that is on July 20 to 24; and bolls which opened on October 9 to 13 were formed from flowers which opened on August 19 to 23. Bolls opening between September 9 and 13 only had 2·50 inches of rain during their critical period of development while, on the other hand, bolls opening between October 9 and 13 had 6·98 inches of rain. The lint of the former was only 49 mm. in length, while that of the latter was 57 mm.

Rainfall during Critical Periods of Bolls Opening on Different Dates.

Date of opening of Bolls.

Days after Flower-Opening	Sept. 9	Sept. 13	Sept. 18	Sept. 23	Sept. 28	Oct. 3	Oct. 9	Oct. 13	Oct. 18	Oct. 23
	Daily Rainfall.									
1	·07	·55	·15	·00	·02	·08	·15	·00	·11	·61
2	·00	·01	·14	·00	·00	·00	·00	·38	·10	·12
3	·21	·18	·05	·00	·00	·01	·00	·21	·02	·00
4	·55	·01	·31	·23	·00	·23	·00	·00	·64	·52
5	·01	·02	·20	·35	·00	·41	·38	·00	·00	2·42
6	·18	·00	·00	·02	·08	·00	·21	·22	·61	·31
7	·01	·15	·00	·00	·00	·15	·00	·11	·12	·00
8	·02	·14	·00	·00	·01	·00	·00	·10	·00	·06
9	·00	·05	·23	·00	·23	·00	·22	·02	·52	·20
10	·15	·31	·35	·00	·41	·00	·11	·61	2·42	·65
11	·14	·20	·02	·08	00	·38	·10	·00	·31	·10
12	·05	·00	·00	·00	·15	·21	·02	·61	·00	·00
13	31	·00	·00	·01	·00	·00	·64	·12	·06	·31
14	·20	·00	·00	·23	·00	·00	·00	·00	·20	·00
	1·90	*1·62*	*1·45*	*·92*	*·90*	*1·47*	*1·83*	*2·41*	*5·10*	*5·30*
15	·00	·23	·00	·41	·00	·22	·61	·52	·65	·04
16	·00	·35	·08	·00	·38	·11	·12	2·42	·10	·30
17	·00	·02	·00	·15	·21	·10	·00	·31	·00	·00
18	·23	·00	·01	·00	·00	·02	·52	·00	·31	·00
19	·35	·00	·23	·00	·00	·64	2·42	·06	·00	·29
20	·02	·00	·41	00	·22	·00	·31	·20	·04	·97
21	·00	·00	·00	·38	·11	·61	·00	·65	·30	·00
	·60	*·60*	*·73*	*·94*	*·92*	*1·70*	*3·98*	*4·16*	*1·40*	*1·60*
22	·00	·08	·15	·21	·10	·12	·06	·10	·00	·00
23	·00	·00	·00	·00	·02	·00	·20	·00	·00	·19
24	·00	·01	·00	·00	·64	·52	·65	·31	·29	·03
Total .	2·50	2·31	2·33	2·07	2·58	3 81	6·72	6·98	6·79	7·12

Another interesting point is noticed if the rainfall table referred to above is examined. It will be seen that during the first fourteen days of the critical periods of bolls opening from September 9 to 13, and October 9 to 13, the difference in rainfall is not great—not more than ½-inch. During the period, however, when it has been found that the rate of growth of cotton lint is at its maximum (Balls : 'Development of Raw Cotton', p. 76), that is, the 15th to 21st days after flower-opening, the difference in rainfall in these two examples is 3½ inches. The 15th to 21st days after flower-opening would therefore seem to be the most important part of the critical period of boll development as far as lint length is concerned.

In the graph which is here reproduced, the total rainfall of the first twenty-four days, in each instance, of the life of the boll is plotted against the lint length ascertained when these bolls opened. It will be seen that there is a definite appearance of correlation between the rainfall of that period and the ultimate lint length attained.

Effect of total rainfall on lint length.

These results seem to indicate, that in these islands the length to which cotton lint will attain in any season is dependent on the water-supply of the plant at the critical period of development of the boll.

To return to the length of lint of the different strains in 1917-18. The plots from which the plants were selected were planted on April 26, 1917, therefore over 60 per cent. of the flowers produced opened during the month of August ; during this period there were only 3 inches of rain. On the other hand, in 1916-17 the rainfall which would have affected the developing bolls amounted to 11 inches—8 inches more than in 1917-18, consequently a great difference in the length of the lint is seen.

In view of these facts, it appears that great caution should be exercised in making comparisons of the length of cotton lint grown in different seasons or in different islands, the rainfall of which is in no way comparable.

REPORT ON THE PREVALENCE OF SOME PESTS AND DISEASES IN THE WEST INDIES DURING 1917.

(*Compiled from the Reports of the principal Local Agricultural Officers.*)

This is the ninth report of this series, the latest previous one, that for 1916, appearing in the *West Indian Bulletin*, Vol. XVI, p. 309. The present report covers the period January to December 1917, and has been prepared in the same way as previous ones, from information supplied by the Agricultural Officers in the several islands.

ENTOMOLOGIST'S VISITS. During the year the Entomologist visited Grenada in January, St. Lucia in July, and St. Vincent in November and December. The main object of the visit to Grenada was to investigate the position of thrips (*Holiothrips rubrocinctus*) as a pest of cacao. A short article on the subject appeared in the *Agricultural News*, Vol. XVI, p 26. St. Lucia was visited with the object of studying the black banana weevil (*Cosmopolites sordidus*). The report of this visit was published as Leaflet No. 11 of the St. Lucia Agricultural Department, and in the Annual Report of that Department for 1917. The visit to St. Vincent was made in connexion with an outbreak of 'bush bugs' (*Nezara viridula*, etc.) on cotton in some localities. The Mycologist was in St Vincent at the same time, investigating the fungi of internal boll disease of cotton. For an account of the situation in St. Vincent reference should be made to the *West Indian Bulletin*, Vol. XVII, No. 1.

MYCOLOGIST'S VISITS. The Mycologist visted Dominica from June 26 to July 11, for the purpose of investigating the occurrence in old-established lime fields of stem rot associated with the growth of bracket fungi. A report dealing with this subject, and with the cultural treatment of young lime trees in process of establishment, as illustrated by the Dominica experiment plots at Morne Bruce, was printed and distributed as a supplement to the *Official Gazette*, and reproduced in the *Agricultural News*, Vol. XI, pp. 334 and 350.

A visit was paid by the same officer to St. Vincent and adjacent islands from October 17 to December 10, for the continuation of studies in diseases of cotton. The report made was printed and locally distributed, and the principal results of the investigations made were embodied in a paper in the *West Indian Bulletin*, Vol. XVII, No. 1.

A projected visited to Montserrat during the cotton season had to be postponed, owing to the difficulties of steamer communication.

CLIMATE.

GRENADA. The dry season was prolonged to the end of June, causing a late cacao crop, and late planting of ground provisions.

The weather was unusually dry in November. This caused premature ripening of yams and consequent shortage in the yield. The rainfall at Richmond Hill was 74·55 inches. Exceptionally heavy rains in July, September and October in Carriacou caused heavy floods, and damage to all crops in flat lowlands.

ST. VINCENT. The rainfall at the Botanic Gardens was 102·35, and at the Experiment Station 88·75 inches. The rainfall of the coast districts was below 80 inches. This has been an excellent season, as the rainfall although below the average was well distributed. The dry season was somewhat prolonged, and cotton and corn planting had in many cases to be deferred until June. The rainfall of November and December was much below normal. The dry weather during these two months cut short the flowering of cotton at the Experiment Station by causing bud shedding.

ST. LUCIA. The rainfall at the Botanic Gardens, Castries, was 85·65 inches or 24·83 inches less than the previous year, and 4·47 inches less than the average for the last twenty-eight years. There was a fairly severe drought from December 1916 to June 9, 1917. Thunder-storms were of almost daily occurrence during the last fortnight of June. On June 29 a severe storm broke over the southern part of the island. The wind averaged 12·5 miles per hour, and shade trees were damaged and blown down owing to the soil being saturated. One estate recorded a fall of 6·76 inches of rain in twenty-four hours. On October 17 another heavy storm was experienced, and a fall of 8·40 inches was recorded at one estate on the leeward coast. Cane cultivation suffered in some districts for the first five months owing to prolonged drought, while cacao cultivation suffered somewhat during the latter part of the year from the heavy storms.

DOMINICA. The rainfall from January to May was normal, but heavy rains occurred during June and on to September. During the latter month torrential rains fell, which resulted in damage to lime and cacao cultivations in the south of the island. From October to December the weather was dry, which is unusual for the time of the year. These remarks apply to the leeward coast and to the Lasoye district. There is always an excess of rain in the inland districts, and an abundance on the windward coast. The weather during the year was generally favourable to crops, and marked a return to normal conditions after the disastrous occurrences of 1915 and 1916. The rainfall at the Botanic Gardens was 80·80 inches.

MONTSERRAT. The rainfall at the Botanic Station was 68·12 inches, which is about 10 inches less than in 1916. The earlier months of the year showed an ample rainfall, the falling off taking place from October to December; actually 17·29 inches less were recorded for these months than in the same period in 1916. Except for a gale on the evening of September 20 which did much damage to areas of cotton, the crops did not suffer unduly from

high winds. There was no prolonged drought during the year, but the rainfall at the close of the year was too small for the full development of the cane crop. The distribution of the rainfall was evidently very favourable for the devolopment of the cotton crop, but in spite of this, the yields on estates were in most cases below the average. The comparatively dry weather in March and April prevented a considerable proportion of the lime blossoms from setting fruit, and a very moderate main crop was reaped.

ANTIGUA. The rainfall at the Botanic Station amounted only to 39·15 inches as compared with 65·05 for 1916. For the first five months of the year only 10·13 inches of rain fell at the Botanic Station. Fairly good rains were experienced in June and November, but the rainfall in July, August, and September was below normal, while October and December were dry months. An indifferent season from an agricultural point of view was experienced, and in consequence, the yields of sugar-cane, cotton, and in some cases, ground provisions will be moderate.

ST. KITTS. The rainfall for the valley or Basseterre district was 39 inches, of which 30 inches fell to the end of September. In the northern districts there were about 55 inches of rain, but this was still below the average for this district. Taking it for the whole of the island, the past year has been most unfavourable for the sugar crop, and to a great extent for the cotton crop also. The sugar-cane crop in the district connected with the sugar factory has so felt the influence of the dry weather that the crop will hardly be one-half of the previous year's. The cotton crop was also affected by the very dry weather of the last three months of the year. There was considerable difficulty in establishing provision and corn crops, and these gave poor returns. High winds were experienced on the night of September 21, but no damage was done to crops.

NEVIS. The rainfall for the year was 44·10 inches, which is 19·94 inches less than that of last year. Most of the rain fell during the early part of the year, and from September to the end of the year the weather was abnormally dry. Very severe weather was experienced during the latter part of September, with strong winds which did a fair amount of damage to the crops in exposed situations. The late cotton was practically a failure on account of the dry weather during the latter part of the year. The cane crop also failed for lack of sufficient rain when it was most needed.

VIRGIN ISLANDS. The rainfall for the year was 38·69 inches, the average for the previous sixteen years being 53·75 inches. The distribution of rain was poor, only June and November showing more than the average rainfall. A cyclonic disturbance passed to the south of Tortola on September 21. The effect of the drought was severely felt, and locally grown provisions were scarce and dear nearly all through the year, this being largely due to unfavourable weather.

PART I.—INSECT PESTS.

BY J. C. HUTSON, B.A., Ph D.,

Acting Entomologist on the Staff of the Imperial Department of Agriculture for the West Indies.

SUGAR-CANE.

MOTH BORER (*Diatraea saccharalis*).

GRENADA. Present, but no damage reported.

ST. VINCENT. Severe in certain districts.

ST. LUCIA. Generally distributed, severe, more particularly on naturally drained lands.

ANTIGUA. Generally present in all cane fields.

ST. KITTS. Generally to be found, but no outbreak during the year.

NEVIS. Not very abundant this year, but observed on nearly all the estates.

VIRGIN ISLANDS. No observations made, but probably present

WEEVIL BORER (*Metamasius sericeus*).

ST. LUCIA. Generally distributed but not serious.

ANTIGUA. General in cane fields. This pest probably does more damage than is realized at the present time.

NEVIS. Not observed on any estate.
VIRGIN ISLANDS. No observations made.

ROOT BORER (*Diaprepes abbreviatus*, and varieties.)

GRENADA. Present in some districts.

ST. LUCIA. Generally present, but not severe.

VIRGIN ISLANDS. Generally distributed, plentiful.

ROOT BORER (*D. famelicus*, *Exophthalmus esuriens*).

ANTIGUA. Found in cane fields on one estate in southern part of island.

ST. KITTS. Large numbers of these in the adult stage were found in the hearts of the young canes in the middle of the year, and on the experiment plots at La Guérite quantities were collected and destroyed. They could be found all over the island.

NEVIS. Adults seen on lime trees, pigeon pea, and on hedges, mainly privet (*Clerodendron aculeatum*).

HARD BACK GRUBS.

ANTIGUA. *Lachnosterna* sp. Common on heavy lands in central part of island. Probably responsible for considerable amount of damage to cane crop.

ST. KITTS. Not seen during the year.

NEVIS. *Ligyrus tumulosus* found in many cane fields, but not known to do damage.

VIRGIN ISLANDS. *Strategus titanus* is frequently to be found in decaying megass, but it is doubtful whether this pest attacks living canes in Tortola.

WHITE ANTS (TERMITES).

GRENADA. Not troublesome on canes.

ANTIGUA. Found commonly on limestone lands in north-west district of the island, but are not regarded as serious pests.

ST. KITTS. These insects have not been recorded from Pond or Buckleys estates as in past years, and seem to be dying out.

CANE FLY (*Stenocranus* [Delphax] *saccharivorus.*)

This insect has not been recorded from any of the islands.

MISCELLANEOUS INSECTS.

GRENADA. Froghopper (*Tomaspis saccharina*). No extension of the infested area, and the infestation has been less severe than last year.

ST. LUCIA. Mealy-bug common in cane fields. Various grasshoppers are well distributed and do minor damage to foliage. There is also a small beetle which does a fair amount of damage to the blades of young cane plants.

DOMINICA. Young shoots attacked by the 'grass looper' (*Remigia repanda*).

ST. KITTS. Grasshoppers caused considerable damage to young canes.

NEVIS. A small amount of damage was done to the young canes by grasshoppers, but they are not considered a serious pest.

COTTON.

COTTON WORM (*Alabama argillacea*).

GRENADA. Not observed. Only small patches of Sea Island and Marie Galante grown in Grenada.

ST. VINCENT. No serious outbreak occurred. A small outbreak on the Windward coast, but this quickly disappeared.

ST. LUCIA. Fairly general wherever cotton trees are found. Cotton is hardly grown as a crop.

MONTSERRAT. Quite normal attacks were experienced on some estates, but these were easily kept in check. The worm was less severe than for several years past.

ANTIGUA. Attacks experienced throughout the season, very severe in October, and November. Showers washed off insecticides when applied, and in some parts of the island a considerable amount of damage was done, especially to peasant-grown cotton.

ST. KITTS. Occurred late in the season in a few places.

NEVIS. The crop was practically free from attacks by cotton worm during the year; there were a few local attacks, but no appreciable damage was done.

VIRGIN ISLANDS. Severe attacks occurred late in the year.

BOLL WORM AND CORN EAR WORM (*Heliothis* and *Laphygma*).

ST. LUCIA. Generally distributed.

MONTSERRAT. These insects are not regarded as cotton pests in the island.

ANTIGUA. Noticed during the year, but little damage done.

ST. KITTS. A few instances of the attack of the corn ear worm were met with, but the damage was slight.

NEVIS. Occurred in a few fields of cotton, but did not cause serious damage.

COTTON STAINERS (*Dysdercus* spp.).

GRENADA. Generally present (*D. delauneyi*).

ST. VINCENT. Occurred locally where control measures were defective (*D. delauneyi*). Locally severe in Bequia.

ST. LUCIA. Generally present, severe.

MONTSERRAT. Appeared at the usual time and were normal in numbers at the close of the year. Probably did less damage than usual. (*Dysdercus* spp.).

ANTIGUA. Noticed in most localities during the latter part of the year, and common in the eastern part of the island. (*D. andreae*).

ST. KITTS. The cotton stainer has been more in evidence during the past season than perhaps ever before. They appeared about November and yielded to no endeavours to reduce their numbers. It is the first occasion on which flights from field to field have been noticed locally. (*D. andreae*).

NEVIS. Generally present, and caused serious damage by infesting cotton with internal boll diseases. May be seen in the island throughout the year near ginneries, and on native plants.

VIRGIN ISLANDS. Few stainers were recorded.

BUSH BUGS (*Nezara viridula*, and others).

GRENADA. Generally present, but caused no damage to cotton.

ST. VINCENT. Fairly generally distributed. The relation of th various plant bugs to cotton in St. Vincent has been dis cussed in a previous number of the *West Indian Bulletin*

MONTSERRAT. Not observed in any numbers in cotton fields.

ANTIGUA. Not abundant, but usually found in most cotton fields.

ST. KITTS. Not observed.

NEVIS. Not known to attack cotton.

VIRGIN ISLANDS. *Nezara viridula* observed in some localities.

BLACK SCALE (*Saissetia nigra*).

WHITE SCALE (*Hemichionaspis minor*).

GRENADA. Generally distributed.

ST. VINCENT. Severe in the leeward district where certain infested trees occurred near cotton fields.

ST. LUCIA. Black scale hardly noticed. White scale found on stray cotton bushes in all the districts.

MONTSERRAT. Only occasionally observed.

ANTIGUA. Commonly found in old cotton plants.

ST. KITTS. The cotton plants are turned under before scales become noticeable.

NEVIS. Observed on cotton, but not until the crop was nearly picked. Not considered pests, as they are not known to attack young plants.

VIRGIN ISLANDS. White scale severe in places, especially parts of Virgin Gorda.

FLOWER-BUD MAGGOT (*Contarinia gossypii*, Felt.).

VIRGIN ISLANDS. No observations made in 1917. There were few indications of its presence in the Experiment Station where it was recorded in 1916.

LEAF-BLISTER MITE (*Eriophyes gossypii*, Banks).

GRENADA. Generally distributed in Carriacou.

ST. VINCENT. Rather more in evidence, due to the careless manner in which the destruction of cotton stalks was carried out. Closer supervision of the work is necessary.

ST. LUCIA. Found wherever cotton is grown, and is serious on poor soil.

MONTSERRAT. Present in normal quantities on the first crop of cotton, but more prevalent than usual on second growth. Not regarded as responsible for much loss of crop.

ANTIGUA. Rather more prevalent than usual during the year, probably due to neglect on the part of planters (especially peasants) to destroy old plants.

ST. KITTS. Leaf-blister mite has attacked the cotton with great severity, and in one district it caused some loss owing to its being carried forward from the previous year on cotton planted too early in the season. This points to the urgent necessity for a close season even in St. Kitts. Generally speaking, this pest only attacks the cotton plants when they are maturing, and they are turned under for planting cane in the land before any damage results.

NEVIS. Fairly abundant this season, partly due to the fact that the older infested cotton is left standing while the young cotton is planted in the immediate neighbourhood. It has also been observed that in cases where the hedges around cotton fields are not kept clean the infestation starts on the plants nearest the hedges, and spreads to other parts of the field.

VIRGIN ISLANDS. Generally distributed.

MISCELLANEOUS INSECTS

ANTIGUA. Isolated attacks of aphis.

NEVIS. Lachnopus was observed in some fields on young cotton, but little damage was done by this weevil. Grasshoppers and the common field cricket were known to attack young cotton in one district.

CACAO.

THRIPS (*Heliothrips rubrocinctus*, Giard.).

GRENADA. Slight extension of area reported. Generally speaking, the severity of the attack has been milder than in 1916. Some control has been effected on small areas by spraying with Bordeaux-nicotine mixture.

ST. VINCENT. Although thrips was generally prevalent, attacks on cacao were not as severe as usual.

ST. LUCIA. Generally distributed, locally severe, particularly on lowlands. This insect has quite a large range of food-plants, including cashew, mango, guava, almond, and cassava. It is serious on cacao.

DOMINICA. Occasionally present, but seldom in sufficient numbers to do appreciable injury.

ST. KITTS. Thrips present on the cacao trees at Molineux estate

BEETLE (*Steirastoma depressum*, L).

GRENADA. Locally severe, chiefly on the western coast.

ACROBAT ANT (*Cremastogaster brevispinosa*, Forel).

GRENADA. Generally distributed, locally severe, occurring chiefly associated with mealy-bug on cacao.

ST. VINCENT. Generally distributed, severe.

SCALE INSECTS AND MEALY-BUGS.

GRENADA. Mealy-bugs generally distributed, locally severe.

ST. LUCIA. Mealy-bug found on young pods and leaves.

DOMINICA. Mealy-bug occasionally met with on cacao trees.

MISCELLANEOUS INSECTS.

GRENADA. Non-tunnelling termites responsible for some damage to cacao trees.

LIMES AND OTHER CITRUS.

SCALE INSECTS.

GRENADA. The purple scale (*Lepidosaphes beckii*), snow scale (*Chionaspis citri*), green scale (*Coccus viridis*), and the West Indian red scale (*Selenaspidus articulatus*), were generally distributed and locally severe on lime trees.

ST. VINCENT. Attacks general and severe

ST. LUCIA. *Chionaspis citri*, generally present, especially in dry districts; *Saissetia nigra* found in fields where ochroes have been grown; *Coccus viridis* generally present, severe on seedlings in nurseries; *Selenaspidus articulatus* generally present on leaves of lime trees, apparently doing little damage; *Lepidosaphes beckii* generally distributed, severe, especially where cultivation is poor.

DOMINICA. Usually present on poor cultivations, and on cultivations in the course of being established. There were several outbreaks of the green scale (*Coccus viridis*), the presence of which is usually marked by a fair amount of black blight.

MONTSERRAT. Green scale less prevalent than for some years. No marked attacks of the purple scale.

ANTIGUA. The West Indian red scale, purple, green, and white scales common.

ST. KITTS. Very little lime cultivation in the island. but scale insects are present wherever limes are grown.

NEVIS. Purple scale severe on all plantations and did a considerable amount of damage on one estate.

BARK BORER (*Leptostylus praemorsus*, Fabr.).

GRENADA. A species of Leptostylus found in collars of lime trees at Morne Rouge.

ST. LUCIA. Generally present, particularly in the northern end of the island. It is not severe, and is kept under control.

ROOT BORER, ROOT GRUBS (*Diaprepes* spp.).

GRENADA. The striped root borer (*Diaprepes abbreviatus*, var.) and an almost white species* damaged lime leaves and twigs.

ST. LUCIA. *Diaprepes abbreviatus* var. known to be fairly well distributed, but damage uncertain.

MONTSERRAT. No observations have been made on the question of root grubs.

ANTIGUA. Large quantities of the adult of the black root borer (*D. famelicus esuriens*) were destroyed on an estate during the month of June. Number estimated at 100,000.

ST. KITTS. The black root borer (*D. famelicus lepidopterus*) is to be found in the adult stage eating the leaves.

NEVIS. Not observed.

MISCELLANEOUS INSECTS.

ST. LUCIA. A small weevil (*Neocyphus pudens*) was fairly common in Soufrière valley on the leaves of lime trees. A species of katydid* damaged the leaves of orange.

SWEET POTATOES.

SCARABEE (*Euscepes batatae*, Waterhouse).

GRENADA. Locally severe.

*Sent to Washington for identification.

ST. VINCENT. Rather troublesome at Experiment Station.

ANTIGUA. Commonly found in potatoes grown by peasants. Potatoes grown on estates are, as a rule, free from this pest.

ST. KITTS. Reported from one district as causing loss.

NEVIS. Locally severe on one estate.

CATERPILLARS (*Protoparce cingulata*, and others).

ST. LUCIA. Caterpillars are generally distributed, and at certain seasons are serious pests.

DOMINICA. No definite observations.

ANTIGUA. *P. cingulata* reported from several localities, but apparently did but little damage.

VIRGIN ISLANDS. *P. cingulata* attacked sweet potato vines rather badly in Virgin Gorda. Not so severe in Tortola.

THRIPS.

GRENADA. Recorded present.

Not observed in any of the other islands.

RED SPIDER (*Tetranychus telarius*, L.).

GRENADA. Generally present.

ST VINCENT. Generally present at Experiment Station.

ANTIGUA. Noticed on plants growing in poor shallow soil.

Not observed in the other islands.

INDIAN CORN.

CATERPILLARS (*Heliothis armiger*, *Laphygma frugiperda*, and others).

GRENADA. *H. armiger* and *L. frugiperda* generally distributed. *Cydosia histrio* occurred locally.

ST. VINCENT. *H. armiger* generally rather scarce this year. *L. frugiperda* not so prevalent this year as last.

ST. LUCIA. *H. armiger*, generally distributed.

ANTIGUA. *H. armiger* invariably present and responsible for a fair amount of damage. *L. frugiperda* noticed during the year.

ST. KITTS. The corn ear worm has caused much loss during the past season, and this was aggravated by the dry weather. This pest attacked the young plants and yielded to treatment with poison bait of Paris green and corn meal, but later on the corn was attacked in the ear.

NEVIS. *H. armiger* very plentiful in some fields.

VIRGIN ISLANDS. Corn planted in the station was attacked by a species of caterpillar, probably the boll worm. The same insect frequently damaged corn in peasants' cultivation.

HARD BACK GRUBS (*Lachnosterna* spp.).

ANTIGUA. The grubs of *Lachnosterna* sp. were in certain localities again responsible for a fair amount of damage to this crop.

MISCELLANEOUS INSECTS.

ST. VINCENT. *Diatraea saccharalis* was very troublesome at the Experiment Station and throughout the island.

ST. LUCIA. Grain weevils were generally distributed, and attacked the corn in the field while ripening and when stored.

ST. KITTS. Adults of *Diaprepes famelicus* could be found in large numbers in the heart of the corn plants.

COCO-NUTS.

WEEVIL (*Rhynchophorus palmarum*, L.).

GRENADA. Generally distributed, locally severe.

ST. LUCIA. Rarely met with.

WHITE FLY (*Aleurodicus cocois*, Curtis).

GRENADA. Generally distributed.

ST. LUCIA. Present, but not serious.

DOMINICA. Present, but not causing much injury.

SCALE INSECTS (*Aspidiotus destructor*, Sign.).

GRENADA. Generally distributed, locally severe.

ST. VINCENT. Locally severe.

ST. LUCIA. Generally present and fairly serious on young trees during dry spells on poor and sandy soils along the coast.

DOMINICA. Present, but no serious injury caused.

ANTIGUA. Fairly common, but does little damage where crop is grown on suitable land.

NEVIS. Observed in all plantations, chiefly on old leaves. Where the soil conditions are unfavourable, this pest is prevalent on young plants.

VIRGIN ISLANDS. Often found on young palms, especially where conditions are somewhat unfavourable for rapid growth, but the palms usually outgrow the attacks.

GROUND NUTS.

PLANT BUGS (*Nezara viridula*, and others).

ST. VINCENT. Generally distributed, locally severe.

ONIONS.

CATERPILLARS, CUT-WORMS.

MONTSERRAT. Onion seedlings are invariably attacked by cutworms in the seed-beds.

ANTIGUA. Common in all onion fields, but do little damage if normal amount of care is taken. Controlled by hand-picking.

NEVIS. Observed in nursery beds and in the field, but not considered serious pests.

VIRGIN ISLANDS. Cut-worms (*Prodenia* sp.) attacked onions, in many cases severely.

THRIPS (*Thrips tabaci*, Lind.).

ANTIGUA. Common in the majority of onion fields when crop is maturing.

NEVIS. Observed in nearly all plantations when the crop is ripening.

MISCELLANEOUS INSECTS.

ANTIGUA. Grubs of *Lachnosterna* sp. attacked onions in some parts of the island. Impossible to grow this crop in badly infested fields.

YAMS.

SCALE INSECTS (*Aspidiotus hartii*, Ckll.).

GRENADA. Generally distributed.

ST. LUCIA. Generally present.

ANTIGUA. Not so commonly found as in previous years.

GREEN DRESSINGS (Beans and Peas).

LEAF-EATING CATERPILLARS.

GRENADA. *Cydosia histrio* attacked black-eye peas in some districts. *Anticarsia gemmatalis* occurred locally on horse beans.

MONTSERRAT. Practically no attacks of woolly pyrol moth (*A. gemmatalis*) have been noticed on Bengal beans during the past season.

ST. KITTS. None observed. During the drought the growing of green dressings has been mainly confined to horse beans, which do not appear to be liable to attacks of caterpillars.

BUSH BUGS (*Nezara viridula*, and others).

GRENADA. Generally distributed.

ST. VINCENT. Generally prevalent, and have done great damage by carrying fungi of internal boll disease of cotton.

ANTIGUA. No observations made.

NEVIS. Nezara was fairiy abundant on peas at the Experiment Station and did a fair amount of damage to the crop.

VIRGIN ISLANDS. These pests usually appear early in the year and are frequently destructive.

MISCELLANEOUS INSECTS.

ST. VINCENT. A weevil which attacks the young seeds of cowpeas, bonavist, and pigeon peas has done great damage in many parts of the island.

The larvae of a small moth (*Ballovia cistipennis*) attacked the pods and seeds of cowpeas in some districts.

Plantains and Bananas.

BLACK WEEVIL BORER (*Cosmopolites sordidus*).

ST. VINCENT. Not recorded to date.

ST. LUCIA. Distributed throughout the island, damage particularly apparent during the dry season. The spread of this insect is materially aided by neglect in examining suckers taken from infested areas to new plantations.

DOMINICA. This pest remains a serious obstacle to plantain cultivation. It also attacks bananas, but not to any considerable extent.

ANTIGUA. No record.

BROWN WEEVIL BORER (*Metamasius sericeus*, Oliv.).

ST. LUCIA. Occurs in banana cultivations.

BLACK HARD BACK BORER (*Tomarus bituberculatus*, Beaud.).

ST. LUCIA. Generally distributed, locally severe, particularly during the spring season and beginning of the rainy season. This pest is spread in the same way as the black weevil borer.

Tannias, Dasheens, Eddoes.

BLACK HARD BACK BORER (*Tomarus bituberculatus*, Beaud.).

ST. LUCIA. Generally distributed, locally severe, particularly during the spring season and beginning of the wet season. Retards the growth and general devolopment of the plant.

MISCELLANEOUS INSECTS AND PESTS NOT OTHERWISE PROVIDED FOR.

ST. LUCIA. The mahogany twig borer (*Hypsipyla grandella*) attacked young trees at the Experiment Station at Réunion.

DOMINICA. The mango maggot (*Anastrepha* sp.) was unusually prevalent during the season, and recommendations were made for its control.

The attacks of wood-boring beetles (ambrosia beetles) which caused so much damage to puncheons and hogsheads used for shipping lime juice were investigated during the year, and recommendations were made for their control.

The 'palute' or slug (*Veronicella occidentalis*), which eats the leaves and shoots of many provision crops was not as much in evidence as in 1915.

ANTIGUA. The larvae of a small moth (probably *Hypsipyla grandella*) were found boring in twigs of mahogany during July and August.

VIRGIN ISLANDS. The longicorn beetle (*Batocera rubus*) continues to be plentiful.

Natural Enemies of Injurious Insects.

PARASITIC AND PREDACEOUS.

GRENADA. The predaceous thrips (*Franklinothrips vespiformis*) was fairly well distributed.

ST. VINCENT. Hymenopterous egg parasites of bush bugs abundant in certain districts.

VIRGIN ISLANDS. No Jack Spaniards have been observed since the cyclone of 1916, and the unusually severe attacks of cotton worm which occurred during the last season are associated with the loss of this natural enemy. It will probably be necessary to re-introduce this useful insect.

PART II.—DISEASES OF ECONOMIC PLANTS.

BY WM. NOWELL, D.I.C.,

Mycologist on the Staff of the Imperial Department of Agriculture for the West Indies.

Sugar-cane.

ROOT DISEASE (*Marasmius Sacchari*, Wakker).

ST. LUCIA. Occurring wherever sugar-cane is cultivated to any great extent, and particularly noticeable on the Bourbon variety.

ANTIGUA. Severe attacks experienced in several parts of the island. Pronounced in fields which had received indifferent cultivation and in some fields of ratoon canes.

NEVIS. Observed on all the estates but not causing serious damage.

VIRGIN ISLANDS. Observed in the Experiment Station; probably present in the bulk of the small holders' plots in the island.

RIND FUNGUS (*Melanconium Sacchari*, Massee).

ST. LUCIA. Occurs particularly in large cane patches on low ground.

ANTIGUA. Commonly found in cane fields.

General Remarks Concerning Sugar-cane.

ANTIGUA. In a number of cases the cane fields were not thoroughly prepared before planting on account of scarcity of labour, and in addition, an indifferent growing season was experienced. These two factors were responsible for a reduced sugar-cane crop.

ST. KITTS. Diseases were not in evidence; the condition directly due to drought was more striking than the effect of any disease experienced.

NEVIS. The cane crop was practically free from fungus diseases, and the poor crop was due to the very unfavourable weather.

VIRGIN ISLANDS. The local sugar industry is in a very bad state. Both cultural and manufacturing methods are hopelessly bad.

COTTON.

SOFT ROT OF BOLLS (*Phytophthora* sp.).

ST. VINCENT. Appeared once, at the beginning of November, at the Experiment Station.

MONTSERRAT. Less prevalent than in 1916.

ST. KITTS. Prevalent, especially in the wetter districts.

WEST INDIAN LEAF MILDEW.

ST. VINCENT. General, late in the season.

MONTSERRAT. No cases of severe attack noticed.

ANTIGUA. Prevalent, but apparently does little damage.

NEVIS. Observed in a few places, but not to any great extent.

BACTERIAL BOLL DISEASE (EXTERNAL).

ST. VINCENT. Less prevalent this year owing to drier conditions

MONTSERRAT. Does not seem to be so common as formerly, and no severe attacks have been noticed.

ANGULAR LEAF SPOT.

ST. VINCENT. Less prevalent.

NEVIS. General, but only when crop was ripening.

INTERNAL BOLL DISEASE.

ST. VINCENT. Locally prevalent in association with green bug infestations. Severe in Bequia and on one estate in St. Vincent in connexion with stainers.

MONTSERRAT. Prevalent as usual in association with cotton stainer infestations.

ANTIGUA. Generally present in cotton fields late in the season. Accounts for a fair amount of damage in some localities.

ST. KITTS. In most cases the stainers only appeared when the bolls were becoming mature. No notable diminution in yield could be attributed to this disease.

NEVIS. Observed in nearly every field, causing a very high percentage of stained cotton. During the latter part of the season very heavy shedding occurred which was also found to be due in great part to this disease.

GENERAL REMARKS CONCERNING COTTON.

ANTIGUA. Some of the cotton fields received very indifferent preparation. Attacks of caterpillars were in some case, neglected. Return per acre expected to be, on the whole indifferent.

ST. KITTS. Besides the diseases of cotton mentioned, there was a tendency in the wetter districts to loss of yield from bolls turning black and drying out. The weather conditions may be held accountable for this in great measure.

CACAO.

ROOT DISEASE (*Rosellinia Pepo*, Pat.).

ST. LUCIA. Occurred particularly in the Soufrière district, and in many plantations in other districts with low wet land difficult to drain.

CANKER (*Phytophthora Faberi*, Maubl.).

ST. LUCIA. Met with in plantations generally, but not very serious. The larger estates are giving the necessary attention to its control.

DOMINICA. Generally distributed on estates. Is particularly fatal to Criollo cacao and also to the Alligator cacao (*Theobroma pentagona*).

BLACK ROT OF PODS (*Phytophthora Faberi*, Maubl.).

ST. LUCIA. Particularly serious in abnormally wet weather in fields in low situations. Very fair attention is given to its control on the larger estates.

DOMINICA. Generally distributed. There is little doubt that canker enters the trees by way of the pods. Young trees of Criollo and Alligator cacao are always free from canker until they begin to bear.

BROWN ROT OF PODS (*Lasiodiplodia Theobromae*, Griff. et Maubl.).

ST. LUCIA. When wet weather occurs in the crop season this disease is particularly serious in low situations where the drainage is imperfect. Rats help considerably in spreading it.

DOMINICA. Present, but can be controlled to a considerable extent by careful disposal of the cacao husks.

DIE-BACK AND STEM DISEASE. (*Lasiodiplodia Theobromae*).

ST. LUCIA. Generally bad; more serious in low situations.

DOMINICA. Always present where the trees are exposed to wind

THREAD BLIGHT.

ST. LUCIA. Noticed in isolated patches; not receiving sufficient attention generally.

GENERAL REMARKS CONCERNING CACAO.

ST. LUCIA. Algal disease (*Cephaleuros mycoidea*) found on most estates at certain periods.

DOMINICA. The cacao industry is rapidly failing in Dominica owing to lack of attention, and to the effects of hurricanes. The export of cacao has fallen off by 75 per cent. in the course of five years.

Limes and Other Citrus Trees.

BLACK ROOT DISEASE (*Rosellinia Pepo*, Pat., and *R. bunodes*, Sacc.).

ST. LUCIA. Few cases reported.

DOMINICA. Owing to depletion of staff, no means exists for obtaining accurate reports on the present position. Conditions require to be again carefully studied, especially in relation to the new situation created by the recent hurricanes, which caused many hundreds of trees to be blown over. Are such trees when renewed by suckers more liable to the disease than those which are restored to an upright position?

UNIDENTIFIED ROOT OR COLLAR DISEASES.

GRENADA. Occurred at the Morne Rouge Station and in adjacent localities.

DOMINICA. Collar disease (foot rot) is noticeable in the case of seedling orange trees; for this reason the life of such trees is a comparatively short one, under average conditions. Only in specially favoured localities are old seedling orange trees met with.

DIE-BACK.

ST. LUCIA. Noticeable on exposed, badly drained, low land.

DOMINICA. Noticeable in places in which the trees are fully exposed to the wind; associated with the critical period of young lime plants, during which time the latter are infested with scale insects; and met with in old lime trees, especially those that have been badly treated during pruning operations, and over-forced by heavy dressings of nitrogenous manures without a backing of humus. Largely controllable by sound methods of agriculture.

MONTSERRAT. The progressive dying back of lime trees has continued.

SEEDLING DISEASES.

ST. LUCIA. Practically no loss during the year, owing to the prevalence of dry weather during the germination stage.

DOMINICA. Damping-off during wet weather occurs every season. So far, it has been easily controlled by dusting the plants with a mixture of equal parts of sulphur and finely sifted lime.

MONTSERRAT. Prevalent as usual during wet periods.

OTHER DISEASES OF LIMES.

DOMINICA. The prevalence of bracket fungi on lime trees was investigated by the Mycologist, his report being published for the information of planters.

Bananas and Plantains.

MARASMIUS ROT (*Marasmius semiustus*, *Mass.*).

ST. LUCIA. Serious in neglected gardens and old ratooned clump

Indian Corn.

rust (*Puccinia Sorghi*, Schw.).

ANTIGUA. Brown rust was fairly common but had little effect on the crop.

ST. KITTS. There was a great deal of rust on the corn grown during the year, and it was found difficult to obtain a paying crop owing to trouble from this affection, and from root disease.

smut.

ANTIGUA. Occurs sporadically.

Ground Nuts.

leaf rust (*Uredo arachidis*, Lagh.).

ST. LUCIA. Occurs wherever ground nuts are grown on wet land.

MONTSERRAT. Plentiful on the experiment plots but not so severe as in 1916.

Coco-nuts.

bud-rot.

GRENADA. Supposed to have occurred at the Botanic Gardens.

ST. LUCIA. Receiving no attention. Cases were met with in the districts of Castries, Anse-la-Raye, Canaries, and Soufrière; they were not numerous.

NEVIS. Bud-rot occurred on one estate and about eighteen trees had to be destroyed. Spraying with Burgundy mixture was carried out and, so far, has checked the spread of the disease.

VIRGIN ISLANDS. Not known to occur.

General Remarks Concerning Coco-nuts.

NEVIS. The plantations are being carefully watched for fresh cases of bud-rot.

VIRGIN ISLANDS. Coco-nut palms were greatly damaged by the cyclone of 1916, some are now recovering.

Onions.

bacterial rot.

MONTSERRAT. Plentiful on the 1917 crop but not so marked as in the previous year.

ANTIGUA. Common, but responsible for little or no damage.

NEVIS. Occurred in plots when the crop was ripening, and caused the loss of a good many onions in damp localities.

General Remarks Concerning Onions.

ANTIGUA. The seed arrived very late. Germination was excellent, and no damping-off was experienced. Dry weather after planting reduced the returns.

Fungi Parasitic on Insects.

ON SCALE INSECTS.

GRENADA. The shield-scale fungus was generally distributed and the remaining common species occurred in moist localities.

ST. LUCIA. The four common species occurred as usual.

DOMINICA. The usual species occurred on lime trees.

ON ANY OTHER INSECT.

GRENADA. The thrips fungus (*Sporotrichum globuliferum*) occurred locally in St. David's parish.

Phanerogamic Parasites.

LOVE VINE.

ST. VINCENT. Kept in check at the Botanic Gardens by a fungus.

ST. LUCIA. Shows a tendency to increase. Attempts to destroy it are generally made with an apparent lack of knowledge of its habits of growth.

DOMINICA. Again reported as spreading to new localities. Some planters are asking for the enactment of legislation on the lines that passed in St. Lucia and Grenada.

ANTIGUA. On one estate several trees infested were destroyed by fire, a ruthless method which proved efficient. One lime estate is rather badly infested.

ST. KITTS. Appears to be increasing in hedges and ravines, but does not attack plants of economic value.

NEVIS. Occurs throughout the island on hedges and cultivated plants. On one estate considerable damage has been done to limes.

VIRGIN ISLANDS. Abundant in nearly all parts of Tortola Apparently increasing in severity.

MISTLETOE.

ST. LUCIA. Fairly common on limes and cacao, but is receiving very fair attention generally.

DOMINICA. The species *Dendropemon caribaeus* caused a lot of damage on certain estates.

VIRGIN ISLANDS. Abundant and locally severe.

Remarks on Other Plant Diseases.

GRENADA. Pigeon pea collar disease at Carriacou slight this year.

Rosellinia root disease was locally prevalent on nutmegs.

SUMMARY OF DISTRIBUTION.

The following table is intended to show the status and distribution of the insects, fungi, and vegetable parasites attacking the principal crops. It has been drawn up from the information available at the Head Office of the Department and has not been re-submitted to the officers in the various islands. While not claiming to be exact, it may be taken as affording a fair summary of the position during the year in question.

EXPLANATION OF SIGNS USED.

g = generally distributed.

G = generally distributed, severe.

l = local.

L = locally severe.

gL = Generally distributed, locally severe.

r = recorded present.

? = doubtful occurrence.

o = no record during the year.

A blank against the pests or diseases of any particular crop means that the crop is not grown at all, or is not important in the island.

INSECT PESTS.

	Grenada.	St. Vincent.	St. Lucia.	Dominica.	Montserrat.	Antigua.	St. Kitts.	Nevis.	Virgin Islands.
PLANTAINS AND BANANAS.									
Black Weevil Borer	–	–	g	G					
Brown Weevil Borer			r						
Black Hard Back Borer ...			g L						
CACAO.									
Thrips	l	g	g L				r		
Beetle	L								
Scale Insects and Mealy-Bugs ...	g L	o	r r				o		
Termites	r								
Root Grubs									
Acrobat Ant	g L	G							
COCO-NUTS.									
Weevil	g L								
White Fly	g		r	r					
Scale Insects	g L	L	g L	r		g		g	g
CORN (INDIAN).									
Corn Ear Worm and Boll Worm	g	g	g			g	g	L	r
Hard Back Grubs							L		
Moth Borer		g							
Mole Cricket									
Corn Leaf Hopper									
COTTON.									
Cotton Worm	o	l			g	g L	l	l	G
Boll Worm and Corn Ear Worm	o	o			o	r	l	r	o
Cotton Stainers	g	l	G		g	g	r	G	r
Scale Insects	g	L	r		r	g	Go	g	L
Flower-bud Maggot	o	o	o		o	o	o	o	o
Leaf-blister Mite	g	g	g		g	g	gL	g	g
Lachnopus								l	
Aphis	o	o	o		o	l	o	o	o
Cryptorhynchus Borer	–	o	–		–	–	–	–	–
Thrips	–	o	–		–	–	–	–	–
Bush Bugs	g	g	o		r	r	o	o	

	Grenada.	St. Vincent.	St. Lucia.	Dominica.	Montserrat.	Antigua.	St. Kitts.	Nevis.	Virgin Islands.
GREEN DRESSINGS.									
Leaf-eating Caterpillars ...	r				o		o		
Bush Bugs	g	G			o	c	o		
GROUND NUTS.									
Green Bugs									
Mealy Bug									
Leaf-eating Caterpillars ...									
Bush Bugs		g L							
LIMES AND OTHER CITRUS TREES									
Scale Insect	g L	G	g L	L	g	g	g	gL	o
Bark Borer	r	g							
Twig Borer									
Root Borer Grubs (*Diaprepes* spp.)	o	o	o	o	o	o	o	o	o
Bagworm									
Diaprepes spp. (Adults)... ...	r	o	r	o	o	L	r	o	o
Mole Cricket									
ONIONS.									
Caterpillars					g	g		r	L
Thrips						g			
Lachnosterna grubs						L			
SUGAR-CANE.									
Moth Borer	r	L	gL			g	g	g	o
Weevil Borer	o	o	g			g	o	o	o
Root Borers (*Diaprepes* spp.) ...	l	o	g			l	g	g	g
Cane Fly	o	o	–			o	o	o	o
Termites	o	o	o			o	o		
Hard Back Grubs (*Lachnosterna*)	o	o	o			l	o	o	o
Froghopper	l	–	–			–	–	–	–
Grasshoppers	o	o	g			o	g	g	o
Mealy-Bug	o	o	g			o	o	o	o
SWEET POTATOES.									
Caterpillars		g		o		r			l
Scarabee	L	l	o		o	l	r	l	o
Thrips	r								
Red Spider	g	l				l			
Slugs									
Sylepta helcitalis									

	Grenada.	St. Vincent.	St. Lucia.	Dominica.	Montserrat.	Antigua.	St. Kitts.	Nevis.	Virgin Islands.
TANNIAS DASHEENS AND EDDOES									
Black hard back borer			gg L						
YAMS.									
Scale Insect	gg	gg				gg			
PLANT DISEASES.									
BANANAS AND PLANTAINS.									
Marasmius Rot.	o	–	gg	o	o	o	o	–	o
CACAO.									
Root Disease	gg		gg	o					
Canker	gg		gg	gg					
Black Pod Rot	gg L		gg	gg					
Brown Pod Rot	gg L		gg	gg					
Die-back and Stem Disease ...	o		gg L	l					
Pink Disease	–		o	o					
Thread Blight	o		l	o					
COCO-NUTS.									
Root Disease	?		o			?		–	–
Bud Rot	?		gg			?		L	o
Leaf Disease	o		gg			o		o	o
CORN (INDIAN).									
Rust	–	o				gg	G	o	
Smut	r	o				l	gg	o	
Root Disease	–	o				?	G	o	
COTTON.									
West Indian Leaf Mildew ...	o	gg			l	gg	o	l	l
Bacterial Boll Disease	o	l			gg	o	o	o	o
Angular Leaf Spot	o	l			o	o	o	gg	o
Black Arm	–	l			o	o	o	o	o
Internal Boll Disease	?	L			gg L	gg L	?	G	?
Phytophthora Soft Rot... ..	–	l			gg	?	gg L	o	o
GROUND NUTS.									
Root Disease		o	o		o	o	o		
Leaf Rust		gg	gg L		gg	l	o		
Leaf Spot		gg	o		o	o	o		

	Grenada.	St. Vincent.	St. Lucia.	Dominica.	Montserrat.	Antigua.	St. Kitts	Nevis.	Virgin Islands.
Guinea corn and Imphee.									
Rust								l	
Smut								o	
Root Disease								o	
Limes and other Citrus Trees.									
Black Root Disease	o		l	L	–				
Red Root Disease	–		–	L	–				
Die-back	o		l	l	g L				
Onions.									
Bacterial Rot		o			g L	g	o	g	o
Sugar cane.									
Root Disease	l		g			L	o	g	g
Rind Fungus	o		g			g	o	o	o
Red Rot			?			o	o	o	o
Pine-apple Disease	–		?			o	o	o	o
Sweet Potatoes.									
Root Disease	–					g	o	o	o
White Rust	–					o	o	o	o
Yams.									
Tuber Disease						o			
Wilt Disease						r			
Phanerogamic Parasites.									
Love Vine	g	g	g	l		L	l	g L	g L
Mistletoe	g	o	g	L		o	o		g L

THE SHRINKAGE OF SOILS.

In an article appearing in this Bulletin (Vol. XII, p 50), Mr. Gilbert Auchinleck summarized the work which had been done by various observers in the West Indies in estimating the shrinkage of wet masses of soil during the process of drying, and in applying the results of the measurements so obtained to determine the general characters of the soils investigated, particularly as regards their clay content, and the application which these observations may have in agricultural practice.

It was recorded that suitable means had been devised for determining the shrinkage, and that the shrinkage appeared to depend on the size of the constituent particles of the soil, and particularly of the amount of clay present. Attempts were made to apply the methods in practical agriculture, and it was shown that they were capable of application in discriminating between soils of different textures. One particular practical application was pointed out, namely, that by this means it is possible to judge with some degree of precision of the fitness, so far as physical characters are concerned, of various soils for the cultivation of cacao, a tree which is very susceptible to soil conditions, and in connexion with which much time and money have been lost by planting in unsuitable soil, the unsuitability only becoming apparent when the trees have attained an age of several years. It was indicated, provisionally, that when the linear shrinkage of a mass of wet surface soil exceeds 10 per cent, the soil is too clayey for the proper growth of the cacao tree: when the observation is made on the subsoil, the limit of permissible linear shrinkage is 12 per cent.; if this is exceeded, the prospects of the tree thriving are poor. It is probably more important in the case of cacao soils to make obseruations on the subsoil than on the surface soil.

For convenience, it may be stated that the observations are readily made by bringing the sample of soil to a proper consistency, either by drying, or by the addition of water, the proper consistency being judged as that in which the sample is in a condition of maximum plasticity, but can be kneaded or moulded without adhering unduly to the hands. Masses of soil so prepared are moulded into the form of bricks $3 \times 1 \times 1$ inches in size into which two fine pins or needles are inserted at a distance of as nearly as possible 50 millimeters apart, the actual distance being found by careful measurement. The bricks are set aside in a cool shady place to dry; they are turned occasionally to promote even drying and to avoid warping; during the process of drying the distance between the pins is measured from time to time until shrinking ceases; the shrinkage is then stated in terms per cent of the original distance between the pins.

Dr. H. A. Tempany, when Government Chemist and Superintendent of Agriculture for the Leeward Islands, made further investigations in connexion with this property of shrinkage of soils, his observations being published in the *Journal of Agricultural Science*, Vol. VIII, Part 3 (June 1917) from which the following is reproduced.

The first point investigated was the relationship between contraction and water loss. For the purpose of the investigation, five typical soil samples were selected, taken from cultivated land in different parts of the Leeward Islands Colony; they are described below :—

A. A heavy slightly calcareous clay loam.
B. A heavy non-calcareous loam.
C. A medium non-calcareous loam.
D. A moderately light non-calcareous loam.
E. A light non-calcareous loam.

The origins of the above soils are respectively as follows: A and B are from Antigua, C is from Nevis, D and E are from Montserrat.

The volume of water requiring to be added to 100 grms. of air-dry soil to produce maximum plasticity, together with the mean total linear shrinkage expressed as a percentage in each case, is given below.

	Volume of water required to produce maximum plasticity c.c. per 100 grms. air-dry soil.	Mean linear shrinkage per cent.
A.	37·0 c.c.	13·0 per cent.
B.	36·0 „	12·1 „
C.	26·0 „	8·8 „
D.	24·0 „	6·0 „
E.	19·0 „	2·9 „

The physical composition of each of the soils in question, as determined by Osborne's beaker method is given below :—

Grade	Diameter of particles. mm.	A.	B.	C.	D.	E.
Stones	5 and over	—	3·6	3·8	7·4	3·0
Coarse Gravel ...	5 to 2 ...	3·3	2·6	6·6	1·7	5·0
Gravel	2 to 1 ...	3·6	5·6	9·1	3·5	7·6
Coarse Sand ...	1 to 0·5 ...	4·5	5·0	6·3	4·0	6·4
Medium Sand ...	0·5 to 0·25 ...	9·2	9·2	15·5	15·6	17·0
Fine Sand	0·25 to 0·1 ..	4·7	2·3	9·5	2·5	12·4
Very Fine Sand ...	0·1 to 0·05 ...	4·3	3·7	4·4	6·2	6·5
Silt	0·05 to 0·01 ...	7·4	7·8	4·7	9·9	11·0
Fine Silt	0·01 to 0·005 ...	47·9	44·1	28·7	37·7	25·6
Clay	less than 0·005	7·4	9·4	7·9	9·1	2·6
Organic matter and combined water	... ...	10·2	6·7	4·7	2·4	2·9
	Total ...	102·5	100·0	101·2	100·0	100·0.

An examination of the above figures will show that although a rough proportionality exists between the shrinkage observed and the content of particles of the fine silt and clay order of

magnitude, the proportionality is by no means exact, and in the case of the samples C and D, the physical analysis would lead one to expect that a slightly greater shrinkage would be found to occur in the cases of D than that of C, while in fact the reverse is actually the case.

In the case of the various experiments the series of trials were in the majority of instances repeated a considerable number of times, and the results obtained represent the mean of a number of independent determinations. It was found that this was the best plan to obtain readings which would give smooth curves, as, in individual instances, tendencies to depart from the smooth form were usually observed. These irregularities most usually tended to occur at the commencement of a series of readings, and were the result of the increased tendency of the blocks to stick to the supporting cage in the wet stage. This objection was partly surmounted by rubbing the interior surface of the cage with graphite, but could not be completely got over. By repeating the experiments a number of times, the irreguularities could however be readily smoothed out.

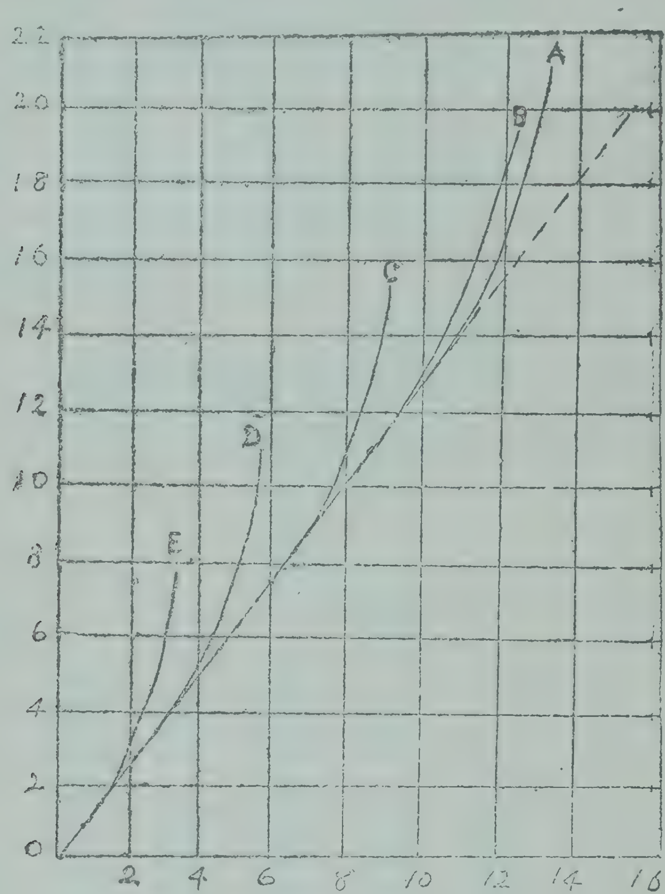
The results are given in the accompanying table ; they are expressed in terms of the water per cent. on the weight of the wet brick, and in the corresponding linear contraction per cent. The results are also displayed graphically in the Diagram on the next page.

A		B		C		D		E	
Water loss per cent. on wet brick.	Shrinkage per cent.	Water loss per cent. on wet brick.	Shrinkage per cent.	Water loss per cent. on wet brick.	Shrinkage per cent.	Water loss per cent. on wet brick.	Shrinkage per cent.	Water loss per cent. on wet brick.	Shrinkage per cent.
2·0	1·55	2·0	1·55	2 0	1·55	2·0	1·55	1·0	·65
4·0	3·1	4·0	3·1	4·0	3·1	4·0	2·90	2·0	1·28
6·0	4·65	6 0	4·65	6·0	4·65	6 0	4·20	3·0	1·48
8·0	6·15	8·0	6·15	8·0	6·0	8·0	4·9	4.0	2·00
10·0	7·8	10·0	7·7	10·0	7·3	10·0	5·5	5·0	2·24
12·0	9·1	12 0	8·9	12·0	8·2	12·0	5·8	6·0	2·50
14·0	10·30	14·0	10·0	13·0	8·6	13·2	6·0	7·0	2·75
16 0	11·3	16·0	11·1	14·0	8·7	—	—	7·8	2·9
18·0	12·17	18·0	11·8	15·0	8·8	—	—	—	—
20·0	12·80	19·0	12·1	—	—	—	—	—	—
21·5	13 0	—	—	—	—	—	—	—	—

The character of the results is striking, and shows that in the earlier stages of the process of evaporation and contraction the per cent. water lost and the corresponding per cent. linear contraction is the same in all cases, and takes the form of a straight line ; as evaporation proceeds however the straight line form is departed from, and the curves evince an upward tendency ; the point of departure from the straight line form varies in the case of the different soils, occurring at a point which is progressively nearer to the point of origin of the curve as the total observed shrinkage diminishes.

The reason underlying these occurrences appears fairly obvious when the mechanism of the process of shrinkage of considered. The effect in question is attributable to the action is

soil colloids, which when soil is moistened form a gel ; successive additions of water to dry soil result in the more and more complete transition to the gel form, until, when the point of maximum plasticity is reached, the gel is in equilibrium. At the point of maximum plasticity it appears probable from the above result that the whole of the water present in the sample is united with the colloids in the gel form, such a conclusion being indicated from the initial form of the curve, and from the fact that varying amounts of water are required to be added to given weights of soil in order to produce maximum plasticity.



Linear shrinkage per cent.

At the point of maximum plasticity the gel skeleton will ramify throughout the soil block, surrounding in its meshes each one of the constituent soil particles. As the gel loses water by evaporation it will contract, and in contracting will tend to draw together the particles of the soil in its meshes.

In any event, internal friction and the inertia of the soil particles will exert a certain degree of resistance to contraction, but in the earlier stages of drying, owing to the fact that the distances separating the particles are relatively large, and the colloidal films relatively thick, the internal resistance will be very small and approximately constant.

As contraction proceeds, however, the constituent particles will approach nearer to one another, and internal friction will in consequence tend to increase. Eventually a point will be reached when the effect of internal friction will become sufficiently pronounced to exert a preceptible retarding effect on the contracting force due to the gel, and this will be evidenced

by a diminution in the rate of contraction in relation to the corresponding rate of water loss, and by a progressive departure from a straight line relationship. In the end the resistance due to these causes will become equal and opposite to the pull of the contracting gel, when further shrinkage will cease. and the continuity of the gel skeleton within the block will become ruptured.

It is to be observed that in such an event, even after shrinkage has ceased, the gel condition continues to be maintained inside the block, and will continue to lose water in the same way as previously, but as the continuity of the gel skeleton throughout the block has become broken, no further shrinkage is evident.

That this is the case is clearly brought out when the total moisture contents of the soils are compared with the proportion of the total water present, which has been evaporated when shrinkage ceases.

This is shown in the following figures which give the mean total moisture contents of each of the soils examined per cent. on the dry soil, and the percentage of the total which has been evaporated at the time when shrinkage ceases :—

	Mean moisture content per 100 grms. of dry soil.	Per cent. of total moisture content evaporated when shrinkage ceases.
A.	42·9	70·0
B.	40·5	67·0
C.	27·0	64·0
D.	25·0	61·0
E.	20·0	52·5

In any particular case the point at which the internal forces opposed to the pull of the contracting gel begin to make themselves felt must depend in large measure on the aggregate thickness of the colloidal film, that is to say, on the amount of colloids present in the sample, and this will also govern the total contraction recorded.

Up to the present, the relationship between contraction and water loss has been considered purely in respect of the linear contraction. It is now convenient to discuss the connexion between linear and cubical contraction and the corresponding water loss.

The cubical contraction can be calculated from the observed linear contraction by means of the formula :—

$$C = (3a - \frac{3a^2}{(10^2)} + \frac{a^3}{10^4},)$$

where $C =$ the cubical contraction per cent.,
$a =$ the linear contraction per cent.

It is to be observed that with quantities of the order of magnitude in question, the terms $-\frac{3a^2}{10^2} + \frac{a^3}{10^4}$ are not sufficiently small as to be negligible in comparison with the term $3a$, so that the relationship between linear and cubical contraction is not the simple linear function which with sufficient accuracy is usually assumed to exist in the case of linear and cubical expansion of solids under the influence of heat.

In point of fact, so soon as the value of a reaches appreciable proportions, the ratio $\frac{\text{Cubical contraction}}{\text{Linear contraction}}$ diminishes rapidly with increases in the value of a.

On the other hand, in the earlier stages, when the value of a is small, the relationship does not depart very greatly from constancy.

If we examine the figures obtained in the case of Example A (in which the linear relationship between linear contraction and water loss has been shown to persist to the furthest point), and calculate the cubical contraction corresponding to the linear shrinkage up to a value of 9 per cent. for the linear shrinkage (at which point departure from the linear relationship becomes evident owing to causes already discussed), we obtain the following values :—

Linear contraction per cent.	Cubical contraction per cent.	Water loss per cent. on wet brick.
2·0	5·9	2·6
4·0	11·5	5·2
6·0	16·9	7·7
8·0	22·1	10·3
9·0	24·6	11·6

If the above figures are plotted, it will be seen that the departure from the linear relationship is not marked.

When we go on to consider the relation between the actual weight of water lost and the corresponding cubical contraction, we are met with the difficulty that, in the results adduced some variation will be experienced owing to the fact that the density of the wet bricks will not be an absolutely constant quantity, owing to variations in the density of the constituent soil particles and in the content of water.

Actual measurements indicate that in the case of the soils examined the density of the wet blocks ranged between 1·95 and 2·1 ; if we assume as an approximation a mean density of 2·0 for the wet block, and compare the actual weight of water lost per unit of cubical contraction for a block which when wet measures 100 c.c., in the case of Example A, over the range of values just examined, we arrive at the following data :—

Water loss.	Cubical contraction.
5·2	5·9
10·4	11·5
15·5	16·9
20·6	22·1
24·6	23·2

Taking into account the fact that in calculating the cubical contraction any errors inherent in the linear measurement are multiplied nearly threefold, it appears reasonable to assume that, under the conditions of the experiment, the cubical contraction is equal to the volume of the water lost by evaporation (when contraction is not influenced by internal friction among soil particles), and that in the case of a pure colloidal clay, this linear

relationship may be expected to hold good until shrinkage ceases altogether.

It follows from the foregoing, that the relationship between linear contraction and water loss is not strictly linear in character, and as the effect observed grows in magnitude, the departure from the straight line relation will become more and more marked.

Conclusions.

1. In soils which have been moistened to the point of maximum plasticity, the whole of the water probably exists in union with the colloidal material present in the soil in the form of a gel.

2. The gel occupies the whole of the interstitial spaces of the soil, and as it loses water by evaporation, draws together the soil particles in its meshes.

3. The normal relation between contraction and water loss in these circumstances appears to be that the cubical contraction observed to take place is equal to the volume of water evaporated from a given quantity of soil, provided that contraction proceeds unrestricted by internal friction among the soil particles.

4. In normal soils contracting in this way, a point is reached at which internal friction among the soil particles offers sufficient resistance to the contracting pull due to the gel as to cause a progressively increasing departure from the normal relationship. The point at which this departure occurs, and the magnitude of the total shrinkage observed, appear to be a function of the amount of colloidal clay contained in any parti ular example.

5. The relation between cubical and linear contraction is in accordance with the equation.

$$C = (3a - \frac{3a^2}{10^2} + \frac{a^3}{10^4})$$

THE RELATIONSHIP BETWEEN CONTRACTION AND THE PERCENTAGE OF COLLOIDAL CLAY.

Additional information concerning the process of shrinkage can be obtained from the study of the amounts of internal pore space existing in blocks of soil prepared in the manner already indicated, which have been allowed to contract to the full extent, and from which any residual water has been removed by subsequent drying to constant weight at 110° C.

Experimental.

The method adopted in performing this measurement consisted in covering the dried and weighed blocks with a coating of paraffin wax, applied in a series of thin layers by means of a brush until the blocks had been rendered thoroughly waterproof. The blocks were then weighed again in air, the difference between the dry weight of the blocks and that of the waxed blocks giving the weight of the wax coating.

Subsequently the blocks were suspended from the hook of a balance and weighed in distilled water at a known temperature, and from the difference between the weight in air and the weight in water, the volume of the waxed blocks calculated.

The specific gravity of the wax employed for coating the blocks was determined experimentally and found to be ·8995, and from the previously ascertained data the volume of the wax coating was calculated, and the nett volume of the dried blocks found by deduction.

Subsequently the apparent density of the blocks was calculated from the data obtained above, the actual density of the soil under examination determined experimentally by means of the specific gravity bottle, and the per cent. pore space in the block calculated by the formula :—

$$P = \frac{D_1 - D_2}{D_1} \times 100.$$

When P is the percentage of pore space in the block, D_1 is the true density of the soil, and D_2 the apparent density of the soil block.

On these lines the internal pore space was determined on contracted and dried blocks of each of the soils A to E, and also on three other soils disignated F, G, and H.

The results of these are given below ; the data are the mean of a number of repetitions of each measurement which gave close ly agreeing results.

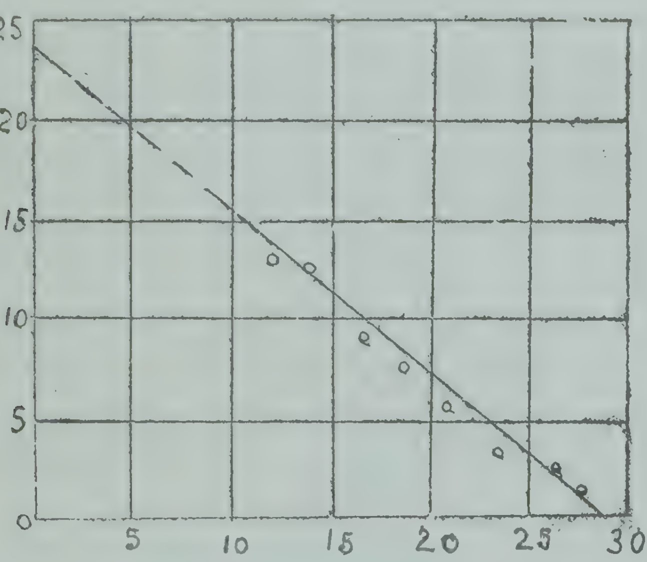
Soil.	Linear contraction.	D_2	D_1	Mean pore space per cent. by volume.
A.	13·0	2·03	2·32	12·5
B.	12·2	1·99	2·30	13·5
C.	8·8	1·97	2·37	16·9
D.	6·0	1·90	2·39	20·5
E.	2·9	1·84	2·41	23·6
F.	6·9	1·85	2·30	19·6
G.	2·0	1·86	2·51	25·9
H.	1·0	1·82	2·52	27·7

The data show a regular increase in the pore space corresponding to the observed decrease in the linear and cubical shrinkage, and when the values obtained for the pore space are plotted against the corresponding values for the shrinkage, the experimental points are found to lie very approximately on a straight line (Fig. 2).

If this curve is extrapolated to cut the vertical ordinate corresponding to the shinkage per cent., it is found that intersection takes place at a value for the shrinkage of 23·5 per cent.

The other extremity of the curve cuts the horizontal ordinate at a point corresponding to a pore space of approximately 28 per cent., which value aproximates to that of the pore space which is found to exist in uncontracted coarse sand of uniform texture

Especial interest centres in the point at which the curve cuts the vertical ordinate; this occurs when the value of the linear shrinkage is equal to 23·5 per cent. At this point the pore space will posses a value of zero. Now if it is assumed that the physical condition of pure dried colloidal clay approximates to that which occurs in continuous matter (such an assumption being presumably justifiable, since the dimensions of colloidal particles, though considerably submolecular, nevertheless commence to approach the molecular order of magnituded), we arrive at the figure obtained by extrapolation as a possible limiting value for the shrinkage of pure colloidal clay.



Pore space per. cent on contracted bricks. Figure 2.

Such an assumption can only be regarded as approximate, since the distance through which the curve has been extrapolated is considerable; on the other hand, by utilizing the value so obtained, it is possible to draw interesting deductions regarding the amount of colloidal clay contained in any sample of soil from a knowledge of the linear shrinkage.

It has already been shown that the observed linear contraction in the case of any particular soil depends directly on the content of colloidal clay, consequently it is obvious that, if the maximum contraction exhibited in the case of pure colloidal clay is known ,it should become readily possible to calculate the proximate content of colloidal clay in any particular example. To effect such a calculation it will be merely necessary to multiply the observed linear shrinkage per cent. by the reciprocal of the limiting value for the shrinkage of colloidal clay, and by 100.

The value of this factor on the basis of the above result is 4·25. Calculations performed in this manner will of course be only approximate, but at the same time they are capable of comparison with known data obtained by other means.

It is a well-known defect of the ordinary methods of physical analysis, that while they are capable of effecting the separation of the coarser particles of the soil with considerable refinement of accuracy, they do not give any exact indication of the amount

of colloidal material contained in the soil, a factor which profoundly affects its agricultural value. In such physical separations the whole of the colloidal material is contained in the four fractions designated silt, fine silt, clay, and organic matter; usually the amount of colloidal material contained in the silt fraction is small, but in the writer's experience, especially in the case of soils containing much colloidal material, it is impossible completely to free the silt fraction from colloidal matter. In the fine silt and clay fractions the bulk of the colloidal material is always contained, but, on the other hand, it frequently happens that much material of a non-colloidal nature is also brought down with the colloidal material, and it is impossile by the ordinary methods of physical analysis to give expression to the actual amount of colloidal material present.

From the foregoing it is obvious that the calculation of the content of colloidal clay by means of a factor of the type indicated above is capable of being checked, inasmuch as, the whole of the colloidal material being contained in the fractions indicated, the total content of colloidal clay cannot exceed the total content of the four fractions in question, and should be generally less. In point of actual practice, since the bulk of the colloidal material is contained in the fine silt and clay fractions, it is sufficient for purposes of comparison to compare the content of colloidal clay calculated from the observed linear shrinkages and the combined contents of fine silt and clay as determined by the methods of physical analysis.

No.	Linear shrinkage per cent.	Content of fine silt and clay as determined by physical analysis per cent.	Content of colloidal clay calculated from linear shrinkage per cent.
A.	13·0	59·3	55
B.	12·1	60·6	51
C.	8·8	45·0	37
D.	6·0	42·1	25
E.	2·9	33·5	12
1	2·0	32·3	9
2	2·7	25·0	11
3	3·1	28·6	13
4	4·0	32·1	17
5	4·5	28·3	19
6	4·7	46·4	20
7	5·0	46·4	21
8	6·0	36·4	25
9	7·0	35·6	30
10	9·0	44·5	38
11	10·0	63·1	43
12	11·4	69·5	48
13	12·0	61·7	51
14	13·0	65·5	55
15	14·0	63·0	60
16	15·0	70·5	64

In the above table these values have been calculated in the case of samples A to E referred to in the first part of this paper, and also in the case of sixteen additional samples of soil drawn from different parts of the Leeward Islands Colony. In this connexion it is well to state, that as the shrinkage determination has been performed on the fine earth samples of the soil in question, from which all particles having a diameter larger than 1 millimetre have been removed, the contents of fine silt and clay have in consequence been recalculated to the fine earth basis. :—

Examination of the above results will show that in all cases the contents of colloidal clay, as calculated from the linear shrinkage by means of the employment of the factor in question, are less than the total content of fine silt and clay as determined by physical analysis, thus strengthening the conclusion already drawn; it is however interesting to observe that, in the case of certain soils, notably A, B, and Nos. 14, 15, and 16, the contents of colloidal clay approach very closely to the total content of fine silt and clay; it is to be remarked that in the case of all these soils, they are particularly difficult to work, especially in very wet or very dry weather.

A further approximate check on the validity of these deductions is capable of being effected if the fine silt and clay fractions of soils of known shrinkage are isolated, and separate determinations of the shrinkage of the separated fine silt and clay fractions carried out, since if the assumptions are correct, and the approximate proportionality existing between the content of colloidal clay in the soil itself, together with the content of fine silt and clay is known, then, since the bulk of the colloidal material is separated in the fine silt and clay fractions, by the employment of the factor in question, it becomes possible to calculate a theoretical value for the shrinkage which should be exhibited by the separated fine silt and clay fractions, and to compare the figure so obtained with the result obtained by actual measurement

This has been done in the case of Examples A and B, and the results are given below :—

	Actual shrinkage observed in the case of the fine silt and clay fractions.	Calculated figure.
A.	20·0 per cent.	21·8 per cent.
B.	18·2 ,,	19·8 ,,

The agreement between the calculated and the theoretica values in both these cases is sufficiently close to afford important confirmation of the conclusion already arrived at, especially when it is borne in mind that the separation of the colloidal clay in the fine silt and clay fractions is not complete, inasmuch as some will remain in the silt fraction.

The deductions arrived at in the foregoing pages indicate that by the employment of a factor of the value indicated, it is possible to calculate the approximate content of colloidal clay in soils from a knowledge of the shrinkage. Such calculations are of course only approximate, but at the same time they would appear to be capable of affording information of considerable value to the

soil analyst, apart from data obtained by the ordinary methods of physical analysis, which, as has been shown, do not afford a complete insight into the character of the soil, inasmuch as they give no expression for the amount of colloidal material therein existing.

It is hoped that, in a subsequent paper, it may be possible to trace the relationship exhibited between the values for the content of colloidal clay calculated from the shrinkage and data derived from a study of the adsorption coefficient of different soil types.

SUMMARY.

1. By determination of the internal pore space in blocks of soils, and comparision with the observed value for the linear shrinkage, it is found that a linear relationship appears to exist between the two values.

2. By extrapolating the curve thus obtained, an approximation for the limiting value of the shrinkage in the case of pure colloidal clay is arrived at, amounting to approximately 23 per cent.

3. On this assumption it becomes possible to calculate the approximate content of colloidal material in any soil from a knowledge of the linear shrinkage.

4. Results are adduced, showing the values obtained for the hrinkage in the case of separated fine silt and clay fractions in the case of two soils of known shrinkage and physical composition, and compared with the values calculated from previous assumptions.

5. The results of the calculation of the content of colloidal clays in the foregoing manner in the case of sixteen Leeward Islands soils are appended.

(Pages 69—118, issued 22nd October, 1918.)

THE AUDUBON SUGAR SCHOOL.

AN EXPERIMENT IN THE EDUCATION OF CHEMICAL ENGINEER

BY DR. CHARLES E. COATES.

In these days of preparedness, the training of chemical engineers has taken on a consequence which is interesting both to the college and the country at large. The part which the chemist has played in modern development we have known in a way for some years, of course, but we are appreciating now as never before, the vital and imperative importance to our nation of a body of men who cannot only discover chemical principles but can also apply them industrially.

At the same time, it has been generally acknowledged that college courses in Chemical Engineering have hitherto been lacking in some essential ingredient. Numerous efforts have been made to remedy this state of affairs. Among the most recent are the industrial fellowship system of the Mellon Institute, and the plan lately outlined by the Massachusetts Institute of Technology, accounts of which have appeared in this Journal. The English journals are full of new schemes for the training of chemical engineers, indeed practically all the larger schools have changed such courses materially within the past few years. In view of this, and inasmuch as experience, after all, is the only safe guide in the jungle of educational theory, it has been thought that a brief sketch of the origin and development of the Audubon Sugar School might not be untimely.

Few people realize how very largely the sugar industry of to day is a chemical industry. A little over a century ago, when sugar was first made from beets, the root was low in sucrose, and

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* Reproduced from the *Journal of Industrial and Engineering Chemistry.*

the process gave a poor yield of an inferior grade of sugar with an almost valueless molasses. The chemist and the agronomist, working together, slowly raised the sucrose content of the beet root until it was more than doubled; the chemist and the engineer, working together, slowly improved the processes until a good yield of sugar was turned out, practically pure, and both the molasses and all the other by-products became sources of profit and not of loss. In consequence the net cost of beet sugar fell year by year until it became a serious competitor of cane sugar, and finally, it was offered at prices closely approaching the cost of cane-sugar production.

The sugar planters of Louisiana, as a class, are certainly among the most intelligent agriculturists in America. Seeing the increasing gravity of the situation, they decided to meet the competition of beet sugar by the same methods which made that competition possible. In the late eighties they called to Louisiana Dr. W. C. Stubbs, and established under his direction the Sugar Experiment Station at Kenner, Louisiana, which was subsequently moved to Audubon Park, on the outskirts of New Orleans. This station was financed entirely by the planters of Louisiana. A complete sugar house was erected on a scale large enough to give commercial results, and altogether, perhaps $100,000 worth of equipment was obtained either by purchase or gift.

As soon as the work was fairly under way, it became evident there were many leaks in the sugar industry as carried on in Louisiana, and that these could be stopped by proper scientific control. But when the planters began to look for chemists and engineers, they were simply not to be obtained. Up to that time the cane-sugar industry throughout the whole world had been carried on largely by rule of thumb. Few men scientifically trained in sugar chemistry were to be found outside of Europe. In 1890, therefore, at a meeting of the Louisiana Sugar Planters' Association, it was decided to establish, in connexion with the Sugar Experiment Station, a school for the training of experts in sugar work. This was placed under the direction of Dr. Stubbs, and was opened in 1891 as the Audubon Sugar School. So far as I know, this was the first instance in America in which any industry established both laboratories for the scientific investigation of its problems, and a school for the college training of men to put the theory into practice.

POST-GRADUATE CHARACTER OF WORK.

As first outlined, the Audubon Sugar School was intended to appeal mainly to graduates of schools of engineering, and the course was distinctly post-graduate in character. The faculty was composed of some of the ablest men in the country, special stress being laid on research work. It soon became evident, however, that the number of college graduates who appreciated the opportunities in the industry was quite small, and that the demand for training came mainly from men who had not received very much under-graduate training. Moreover, there were a number of applicants from tropical countries, whose preliminary studies had been of such a type as to make it impossible for them

to take up, successfully, the advanced scientific work offered in the Sugar School. At the outset, therefore, the greater number of students were special students, very un-uniform in educational training, which, of course, handicapped the school materially. The course was two years in length, classes were held at the Experiment Station, and during the sugar season the students did the actual work in the fields, in the laboratory, and in the sugar house.

The school was successful from the outset, and in a couple of years more students were applying for admission than could well be accommodated. In the meantime the Sugar Experiment Station was taken over by the State of Louisiana as part of the Louisiana State University, and the Planters' Association withdrew its financial support. With limited funds, the increasing demands upon its staff along purely research lines, and the growing magnitude of its routine work, the Station found it impossible to handle students also. In 1896 the school was accordingly incorporated with the Louisiana State University, preserving the name by which it had become known. In 1908 its numerical importance was such that it was reorganized as a college of the University.

From the first, the writer and his colleagues were given a free hand by President Boyd in formulating the course of study, and changes were made year by year as experience or circumstances dictated. As the instruction was now given by the regular university staff, the students were, of necessity, ordinary college students, subject to the college entrance requirements. Moreover, as the chemical, mechanical, and agricultural subjects having to do with sugar technology had to be based upon chemistry, physics, mathematics, and the biological sciences, it was necessary to require these subjects of all those taking up the purely sugar work. The enforcement of these two regulations worked, at the beginning, to eliminate a number of applicants whom the University would have been glad to welcome, if possible. They were, for the most part, men of maturity, from twenty-five to forty years of age, who had had previous experience in sugar house work, and were anxious to supplement their experience with a certain amount of theory. For several years the University received these men as special students, but it soon became evident that, in spite of their laudable ambition, they were, in nine cases out of ten, merely wasting their time. They were taught certain things in a mechanical way, such, for instance, as how to polarize sugar, but they did not know the principles on which these things depended, and their studies did not lead them anywhere. They were deceiving themselves in thinking they were studying sugar chemistry when they were merely becoming chemical mechanics. Only after it was too late did they recognize the necessity for the foundations and the futility of short cuts to learning. From the beginning, the writer counselled these men against their undertaking, but, as they were ordinarily both intelligent and self-confident, he could not keep them from following their own ideas. Finally, the advanced courses were closed to students of this type. We expected some criticism at first, but none came. The questions which were asked by certain

men as to why they could not be admitted were readily answered to their complete satisfaction.

As men of this class present, collectively, a problem of a general nature, I may say here that I do not believe that it is possible to receive them in the same classes with the ordinary college student. The latter is presupposed to have a certain fairly uniform preparation for his work; the preparation of the former, on the other hand, is almost always inadequate, and much has been forgotten of what had once been known. The college student, therefore, can be taught in the conventional way, but men of maturity must be taught each as a separate problem, with different difficulties to solve. Then, again, the college student is joyfully ignorant of practical experience and responsibilities, and the college teacher must bring these home to him as best he may; the practical man, on the other hand, has learned them in the school of hard knocks, and not infrequently comes better equipped than his teacher, so that what is good advice to one man is a platitude to the other. But the greatest difficulty in teaching the practical man lies in his unwillingness to fill in the gaps in his training. He probably knows no mathematics, and without this he cannot study to advantage college physics, without which problems in mechanics and machinery are unintelligible. The same holds along other lines.

The purpose of the school when first organized was to offer to the citizens of Louisiana the opportunity to secure such training as would qualify them to enter most advantageously the sugar industry of the State. The underlying idea, therefore, was to train men who would be competent to manage plantations which both grew cane and made sugar; that is to say, they were to be trained in agriculture, engineering, and chemistry.

FOUR-YEAR COURSE CHANGED TO FIVE.

The course, as formulated in 1897, was four years in length. During the last two years the students spent the sugar season at the Sugar Experiment Station at Audubon Park in practical sugar house work. It soon became clear, however, that a satisfactory foundation could not be given to high school graduates in two years, so in 1899 the course was made five years in length the first three years being devoted entirely to foundation subjects, and all technology being avoided During the fourth and fifth years the student was sent, as heretofore, to the sugar house at Audubon Park, returning at the end of the sugar season, and taking up his work for the rest of the year. At the end of the fifth year the graduates received the degree of Bachelor of Science. Here, too, there was a little dissatisfaction. The Sugar School students thought that if the engineering students received their B.Sc. degree at the end of the fourth year, so should they. At the end of the fifth year they could then receive another degree. There was a certain specious justice in this claim, but it was not granted. At the end of the fourth year the sugar school student would not be sufficiently trained. If he were to receive a degree then, however, he would be more than likely not to appreciate the deficiencies in his training. A degree is a summum bonum—an end in

itself to most college students. These students were also anxious to get into practical work. Why work a year longer for a degree when they already had a degree? This argument would have been conclusive with many students and most parents. So the course was fixed at five years, and the student got his B.Sc. degree in five years instead of four. This was done because the five years were necessary, and those who did not like it were told it was a rule of the school, and could not be changed. The results justified the means, and to-day the students take special pride in this particular feature of the course.

There was some fear at first on the part of the authorities, that a five years' course would drive away the desirable students, but such has not been the case. As a matter of fact the Sugar School has had more students than it could well care for, and they have been men of an exceptionally high class, which merely goes to prove again that, in matters educational, if a thing is well worth while, the best men do not count the price, whether in time or money. So far as the writer knows, this was the first five years' course in Chemical Engineering ever offered in this country.

From the beginning, there was a strong demand for the graduates of the Sugar School. Ordinarily they were placed six months before they graduated, and, as they made good without any exceptions, the requests became year by year more pressing. Most of the larger sugar houses began to put in laboratories, and chemical control slowly displaced the old rule of thumb. About 1901 the demand for chemists became so great that two of the best fifth-year men were allowed to omit the second year of the practical course at Audubon Park. Instead they were sent to a sugar factory, where they were paid the regular salary of an assistant chemist and worked through the season under strictly commercial conditions, returning to the University when the season was over. It was immediately apparent that these men had gained something which gave them a marked advantage over those students who were taking the routine fifth-year course at Audubon Park, but it was a little hard to tell wherein this advantage lay. Perhaps each man had benefited in a different way. To one it gave self-confidence, to another an appreciation of actual working conditions, to a third a knowledge of men as distinguished from boys, to all a certain sense of responsibility and a maturer point of view.

FACTORY WORK IN THE FIFTH YEAR.

The fifth-year's practical course had been formulated and carried out at Audubon Park and in the laboratory with great care. It contained many things which the student, by going to a factory, would not get, and which it was desirable he should get, so the actual factory practice was permitted with some degree of reluctance, and a little fear that we were making a concession to a popular demand. But its undoubted advantage, largely psychological, over the routine course was so marked, that in 1903 the sending out of the fifth-year students became a part of the established policy of the School, and has remained so ever since. The planters met the movement more than half-way, and

have given the students every possible assistance. These young men receive the same salary as other assistant chemists, and for more than ten years there has not been one who failed to receive employment. An incidental, but most important result has been the strengthening of the relationship between the sugar planters of Louisiana and the Louisiana State University. The students bring back to the University an intimate knowledge of the actual conditions in the various sugar houses, and of the practical problems which are continually presenting themselves. The planters, on the other hand, discuss these conditions and these problems with the various officials of the Sugar School, sometimes personally, sometimes by correspondence, but always with perfect freedom.

In order to get a certain breadth of view as to the Louisiana cane-sugar industry, it has been the custom of the writer to visit the various plantations during the sugar season. After a good many years of personal experience, the writer has come to the definite conclusion that this personal contact between the students and teachers in the School of Chemical Engineering on the one hand, and the chemical plant, together with its responsible officials, on the other hand, is absolutely necessary if the school is to attain even reasonable efficiency. In each industry this contact may be obtained in a different way. In the Audubon Sugar School the practical method has just been outlined.

As these students are absent from the University in the fourth and fifth years for eight to ten weeks of the first term during the sugar season, they cannot be taught in the same classes with other students during the eight or ten weeks when they are present. They are, therefore, taught in different sections from the other students during the first term, the second term, of course, presenting no difficulties. This method placed some extra labour on the teaching staff, but it was the only logical way, and has worked well in practice. There seems to be no reason why it could not be applied more generally to the articulation of courses of chemical engineering with the various industries studied. In this connexion, the writer might say that he is convinced that in the fifth year of a course in chemical engineering, the student should get away from generalizations and try to master reasonably well the details of some one particular industry. The confidence in his own ability, which a student gains by thus narrowing his field of study, stays with him, should he, by chance, find his opportunity in some other line of chemical industry.

INTRODUCTION OF AGRICULTURAL AND ELECTRICAL COURSES.

As soon as the Sugar School was fairly under way, students began to come from all parts of the world, and as at the time it was easier to secure a position as a sugar chemist than as a sugar agriculturist, there was a tendency on the part of the student to stress Chemistry and Engineering at the expense of Agriculture. This tendency was encouraged by the unsatisfactory state of agricultural teaching twenty years ago. As the old professor of agriculture slowly began to resolve into his component parts, and the Professors of Agronomy, Soil Physics, Animal Industry

and the like took his place, there was a notable tightening up along all lines of agricultural pedagogy. Full-term courses were offered where two or three weeks had sufficed, and the increased efficiency of agricultural teaching began to appeal to students generally. But the Sugar School students found themselves in need of a very special type of tropical and subtropical agriculture, where the conditions were altogether unlike those in ordinary American agronomy. To meet this demand, it was decided in 1907, to offer such courses in sugar agriculture in the last three years of the Sugar School, these applying specifically to the conditions on cane plantations in Louisiana. At about the same time Congress made it possible for the Experiment Stations to do experimental work in Mechanical Engineering. In Louisiana this work was placed in charge of Professor E. W. Kerr, as professor of Mechanical Engineering in the Audubon Sugar School, and was concentrated on the specific problems in the sugar houses of Louisiana, such, for instance, as evaporation, bagasse burning, boiler efficiency, and the like. As new fields in Sugar Agriculture and Sugar Mechanics began to develop, it became evident that even five years was not sufficient time to give students satisfactory courses in these and in Sugar Chemistry as well, so, in 1912 a course was formulated in Sugar Agriculture, with Professor A. F. Kidder in charge of the special work in agriculture, being distinct from Sugar Engineering, which included Chemistry and Engineering. The practical work of the plantations and at Audubon Park was the same for each course. The student chooses one course or the other at the beginning of his junior year, and as there is an increased number of openings for scientific agriculturists in sugar countries, this division has its fair share of students. It is possible that students under exceptional circumstances might find it desirable to specialize in Sugar Agriculture and Engineering, leaving out most of the work in Chemistry. Though no demand for this year has yet arisen, the courses are so formulated that the demand can be met without any difficulty.

It is fair to infer from our experience in this respect that, after a school of Chemical Engineering has been mainly associated with some given industry for a term of years, it would become necessary to arrange that the students have suitable latitude in elective subjects for the last year of the course. For instance, during the last year or two many of the larger sugar mills have been changing over from the steam drive to the electric drive, and is generally believed that electrically driven machinery will largely surplant steam driven machinery in the near future. For this reason there has arisen lately a demand for more Electrical Engineering in the sugar course, which demand we are now prepared to meet by offering as electives, special courses in that subject.

ADMISSION OF COLLEGE GRADUATES.

As the value of scientifically trained men became recognized by the sugar industry through the world, students came to Louisiana from practically all the sugar-producing countries. Japan, China, the Philippines, Mauritius, Tahiti, Hawaii, South Africa, France, Spain, Italy, Germany, Sweeden, Norway, Eng-

land, and every one of the South and Central American countries have sent students to the Sugar School. In many cases these were already college graduates, and there was some difficulty in articulating their previous training with the regular sugar course. The first three years of the Sugar School, however, are devoted to pure science, and technology is avoided as far as possible. Students get Mathematics through Calculus, Inorganic, Organic, and Analytical Chemistry, two years each of Physics, Mechanical Drawing, Mechanical Engineering, and one year of Electrical Engineering, together with English and some foreign language. As these subjects are covered in the Chemical Engineering courses at Cornell, Boston Tech., Illinois, and other standard institutions, we decided to credit the first three years' work done in such institutions as for the first three years of the Sugar School, without endeavouring to make a substitution of subject for subject. The last two years of the Sugar School, therefore, were made, as far as possible, of graduate nature, open to students who had had three or four years of college training, and who were prepared to take the courses offered. In this class there have been graduates of various universities both in the United States and abroad. These have been matriculated as graduate students, candidates for the degree of M.Sc. Their courses have ranged from one to two years in length, depending upon the nature of the preliminary training. This system of articulation of a highly technical course with an under-graduate degree has been in use now for about twelve or fifteen years, and has worked out admirably, because of the elasticity in electives permissible to the graduate student. There has been a decided tendency on the part of the graduates in Mechanical, Electrical, and Chemical Engineering to apply for graduate courses in the Sugar School. We have arranged courses for such students, and have found that they can cover nearly twice as much ground in a year as can the average under graduate. A number of these men have gone into practical work with uniform success. In other words, the attitude of the Sugar School towards graduate students is something like this. For the mature man who is a college graduate and wants to take up this kind of work, it is fair to assume that he knows what he wants, so he is treated not as a boy, but as a man, and, in electing his course, he is allowed every latitude compatible with common-sense. For instance, these courses hitherto have included the practical course at Audubon Park and some sugar-house experience, but both these requirements would be waived in the case of the man who was already familiar with sugar-house processes.

As at present organized, then, the course of the Audubon Sugar School is five years in length, and leads to the degree of B.Sc. The first three years are given to general scientific training similar in type to that given in most standard schools of Chemical Engineering. The technical work is given entirely in the last two years, which, therefore, include most of its distinctive features. As the method of articulating the practical and the theoretical is the result of a number of years of experiment and experience, it might not be amiss to give it in detail. At the beginning of the fourth and fifth years the student reports to the University about September 20. He stays there

until the opening of the sugar season, the date of which depends somewhat upon crop conditions, but ordinarily ranges between October 18 and 25. This gives him one full academic month at the university. The sugar season in Louisiana lasts until from December 10 to 25, some smaller estates finishing earlier, and a few larger ones somewhat later. The university assumes that they all close before the end of the Christmas holidays, at which date the student must again report to his classes. This gives him one academic month before the mid-term examinations in February. He is therefore present at the university during the first and last month of the first term, and is working at the sugar house during the second and third months, allowing a margin of about a week for overlapping, due to crop conditions.

FOURTH-YEAR WORK.

The subjects taken by these students while at the university during these two months are of two types. The first type is strictly technical and special, as for example sugar-house control, sugar-machine design and sugar chemistry. Lectures in these subjects stop when the student leaves the university, and begin when he returns. The second type includes general engineering and chemical subjects which are elected by other students, such as the modynamics and machine design. The Sugar School students take half the usual number of such subjects for twice the usual number of hours per week, which requires extra sections During the second term they report with the regular college classes in all subjects. This increases the work of the instructors for the first and fourth month, and lessens it for the second and third, but as the number of class hours involved is not large, the method has worked well in practice. Laboratory subjects present, of course, no special difficulties.

During the first month of the fourth and fifth years all the students concentrate mainly on the technical chemistry and engineering of sugar-house practice. As considerable planting is done during this period, they also visit the plantations under the direction of the Professor of Agronomy, as occasion presents itself. The whole sugar squad is under the general charge of a special instructor in sugar technology, who is generally one of the superintendents of one of the larger tropical sugar houses, and is thus in immediate touch with the industry in its most recent developments. He accompanies the fourth year sugar squad to the Sugar Experiment Station, Audubon Park, New Orleans, and remains with them during the sugar season, at the close of which period he leaves for his regular work in Cuba or elsewhere.

When these fourth-year students reach Audubon Park, they have been drilled in the routine analytical processes of sugar-house laboratories, and in the general mechanical principles of sugar-house machinery. At Audubon Park, the University has a sugar house, cane fields, chemical laboratories—both control and research—bacteriological and entomological laboratories, and a full equipment of all apparatus necessary for the investigation of any ordinary problem, chemical, mechanical, or agricultural which might arise in connexion with the cane-sugar industry,

the whole representing an investment of something over $100,000. Under the direction of an instructor, the student squad is brought into personal contact with each of these various lines of activity, and, to the same end, the squad is visited once a week by the Dean of the Sugar School, the Professor of Mechanical Engineering, or the Professor of Agronomy. The United States Government maintains at the Park a department for the investigation of insects injurious to cane, and the students must keep up with the progress of these investigations. Immediately after reaching the Park, the students are put to work planting cane. This fall planting is finished in three or four days, and is done by the students themselves in the most approved manner under the supervision of the Director of the Sugar Experiment Station. At the end of this time the field hands begin to cut cane and deliver it to the sugar house. Thereupon the sugar squad is divided into ten sections, which are assigned each to a specific station. The sugar house has a nine-roller mill, grinding somewhat less than one ton of cane per hour, the juice being discharged into a cane weigher. This is Station I, and the work is done by one division of the squad. From the weighing tank the juice passes to the sulphuring and liming tanks, which make up Station II ; thence to the open clarifiers ; Station III ; thence to the settling tanks and filter presses, Station IV ; thence to the double effects, Station V. The syrup from the double effect passes to the vacuum pans, Station VI ; and the grained massecuite passes to the mixer and centrifugal, Station VII. There are also bag filters, plate presses, and a Sweetland press through which the juices are run for experimental purposes ; these make up Station VIII. There are around the house a number of small engines and pumps ; the care of these make up Station IX. To each of these stations a small squad of students is detailed for two or three days, so that every man makes the round of the stations about twice. The chemical control is Station X, and rotates with the others. Samples are taken of the cane, the juice, the press cake, the bagasse, the syrup, the massecuite, and the molasses, and the requisite analyses made. A very elaborate system of chemical control has been instituted in as great detail as in the 2,000-ton houses, specially printed blanks being provided for the purpose, the whole system being practically identical with that of the larger Cuban and Porto Rican sugar corporation. The laboratory is provided with an adding machine and also one for multiplying and dividing, so that the students may become familiar with these important labour-saving devices. Complete daily and weekly reports are made out, and special stress is laid on the arithmetical side of sugar-house control. The importance of this phase of chemical engineering is sometimes overlooked. It not only helps to make the chemist a more valuable employee, but it also helps him to realize what he is doing, and why.

From the engineering standpoint, in addition to the foregoing stations, certain squads make detailed reports on the efficiency of the various pumps, the mills, and the evaporating apparatus. From the agricultural standpoint other squads study the result of the field experiments at Audubon Park for the last twenty-five years, and learn the practical methods employed in agricultural research as applied to sugar-cane.

During the fonrth-year season, the squad is sent, two at a time, to the State sugar factory at Angola, La., a 1,500 ton house, thoroughly equipped for making either white or 96° test sugar. Here they help in carrying out sugar-house control on the large scale, and under competent direction.

FIFTH-YEAR WORK.

At the end of their first season, therefore, the students are fairly familiar with the technique of every part of the sugar house, though, of course, they are not skilled artisans. They are able to make out a complete report on the chemical control of the sugar house, and, to some extent, on the chemical efficiency of the process. In the case of the students in sugar agriculture, they can also make out a report on the condition of the cane fields, and their various agricultural requirements, such as fertilizers, drainage, and the like. Most of the work on the purely theoretical side of both sugar chemistry and sugar engineering is given to the students on their return to the university, to which end a special equipment has been provided. For instance, there has been installed an elaborate apparatus for the experimental investigation of evaporation, which has made possible a considerable quantity of research work along this line.

The fifth-year students also put in the first month at the university, concentrating on the details of various phases of sugar technology, and paying special attention to speed and accuracy in their analytical work. They likewise study the principles underlying the various instruments they are to use in the chemical and mechanical control of the sugar house—as for example, the polariscope and the indicator card. When the season opens they go into actual sugar-house practice at various factories over the State, and stay through the sugar season. These students are treated simply as employees, are given no special favours, and expect none. They draw the same salary as any other sugar chemist, and hold their positions only on their merit. The Dean of the Sugar School makes an annual inspection of these factories during the sugar season, and thus learns both what the students are doing, and what the management expects them to do. After their return to the university at the end of the sugar season, they devote the rest of the year to the various subjects outlined in their courses.

The fourth and fifth years of the Sugar School, therefore, are quite special in their nature, and are open to graduates and senior students of standard schools of engineering. The student of the graduate type is classed according to his preliminary training, and allowed to elect such subjects as he may be able to carry out profitably, the utmost latitude being given him.

The Audubon Sugar School is now twenty-five years old. The number of students during the past five years has been 124, 94, 65, 70, 75. The School graduates each year from ten to twenty-five students. These young men have made good without exception. They are scattered all over the sugar world, and occupy many of the most important positions in the sugar industry, which facts are taken to indicate that the School is founded upon correct pedagogic principles.

CODE OF ETHICS.

Just one thing more might be mentioned in closing. It is somewhat difficult to discuss this, and yet its extreme importance is beyond question. From the time the student enters the Audubon Sugar School until he leaves, it is the writer's custom to call frequent attention to the fact that no student can hope to learn much chemistry, or mechanics, or anything else of that sort at college. He merely learns where the literature is, what the problems are, and how to study them for himself personally. One thing, however, he can learn at college, and that is the standard of character necessary for success in Chemical Engineering. These men are not expected to stay engineers or chemists; such positions are only stepping-stones. Each man should hope to be, at some time, a Superintendent or Administrator, and if positions of this type are to be won by merit, that merit must include absolute personal integrity. Any lapse from the highest possible code of honour will destroy the usefulness of a chemist or a superintendent. Absolute truthfulness in work and in reports, loyalty, willingness to co-operate—these things are essential to the highest success in the sugar business.

This is the code of the students in the Sugar School, insisted upon by themselves from the time they enter the university. Lapses are treated with the rude but efficient justice of student self-government, and, by the time a man graduates, these standards are ground into him, and are part of his professional character. It is a matter of record in the Sugar School that in all the years of its history there has not yet been one of its alumni to prove recreant to its personal standards during the after years of his actual contact with the business world. The graduates of the Sugar School are more or less well trained in the sugar industry, fair scientists or excellent, as the case may be, but in all instances they are honourable men, trustworthy, and loyal. They have had this record for a quarter of a century without a break. This is the one point of which the Audubon Sugar School feels it has a right to be proud.

SWINE FEVER.

[Owing to the fact that there is some confusion between several forms of swine diseases, and some differences of opinion as to methods of treatment, it is desirable that reliable information should be available by those interested in the subject. Accordingly the following article on the subject by Professor Sir John McFadyean, M.B., B.Sc., C.M., Principal of the Royal Veterinary College, London, is reprinted from the *Journal of the Royal Agricultural Society of England.* Vol. 78, 1917.—Ed. *W. I. B.*]

THE CAUSE OF THE DISEASE.

A good many points in connexion with swine fever are still in doubt, but it has long been known with certainty that it spreads by contagion. It follows from this that the cause of the disease must be a living organism which multiplies in the bodies of infected animals, and is passed on from the diseased to the healthy. In what may be termed the pre-bacteriological days of pathology, nothing more precise than this could be said of the cause of any of the contagious or infectious diseases of man or the lower animals, and in the absence of any knowledge regarding the nature or form of the cause, it was vaguely termed the 'virus' of the disease. The methods of investigation which were introduced by Pasteur and Koch gradually showed that in the case of many diseases, what had previously been called the virus was a micro-parasite, large enough to be seen with the microscope in the blood or tissues of diseased subjects, capable of being cultivated artifically outside the body, and able to determine an attack of the disease when experimentally introduced into the bodies of susceptible animals. In this way it was proved that different species of bacteria, each possessing distinctive characters, were respectively the cause of anthrax, glanders, tuberculosis, etc., and naturally, thereafter the word virus dropped out of use in speaking of the cause of these diseases.

Unfortunately there are still over a score of contagious or infectious diseases of man and the domesticated animals in which all attempts to discover a demonstrable bacterium or other micro-parasite as the cause have hitherto failed, and one of these is swine fever. In speaking of the cause of that disease, therefore, one has still to use the term 'virus.'

In nearly all the diseases of this group evidence has been produced which makes it probable that the virus is invisible because of the very minute size of the individual bacteria of which it is presumably composed. In favour of this view it may be said that there is nothing *a priori* improbable about it, for although the known bacteria, such as those of anthrax and tuberculosis, are very small things, there does not appear to be any sound reason for denying that bacteria twenty times smaller may exist in nature. But the actual evidence that the living things which constitute the virus of swine fever and other diseases of this class are exceptionally minute, is that they pass readily through filters which arrest any of the visible bacteria. It is easy to show, for example, that if one mixes together in

water, in the same tube, some blood from a case of swine fever (which must contain the virus since it can be successfully used to infect a pig with the disease), and large numbers of the bacilli of glanders or tuberculosis, and passes the mixture through an appropriate filter, the liquid which comes through contains neither glanders nor tubercle bacilli, but does contain some of the germs of swine fever, since it causes swine fever if injected into a pig.

On evidence of this kind the group of diseases referred to above are often said to be caused by ultra-visible organisms, or by filter-passers.

A curious fact with regard to nearly all these filter-passers, including the virus of swine fever, is that they have hitherto resisted all attempts to induce them to grow under what may be termed artficial conditions, outside the body. This is a fact even more to be regretted than their individual invisibility, for an immense amount of knowledge regarding contagious diseases has been gained by studying and experimenting with artificial cultures of the bacteria which are the cause of them. This failure to cultivate the ultra-visible viruses is, of course, not explained by the fact, or hypothesis, that the bacteria of which they are composed are extremely minute, and it must be admitted that no satisfactory explanation of their refusal to multiply outside the body can at present be offered.

Although it is now generally accepted that swine fever is caused by an ultra-visible virus, and not by anything that can be cultivated artificially or made visible with the microscope, it is necessary to refer here to an organism, which, on evidence that appeared to be satisfactory, was for a number of years believed to be the cause of the disease, and therefore termed the swine fever bacillus. The bacillus is almost constantly present in the blood of pigs that are seriously ill from swine fever, and it can also be detected in the lymphatic glands and other parts of the body. It is to be noted that if the examination is made immediately after death this organism is not only found in the positions mentioned, but is generally present in a state of purity, unaccompanied by any other visible bacteria. By feeding or inoculating with artificial cultures of this bacillus, pigs can be made ill and even fatally infected, and when they die or are killed, the *post-mortem* examination generally shows diseases of the intestines iudistinguishable from what is common in cases of swine fever. In short, it appeared that this must be the cause of swine fever, since it seemed to be constantly present in cases of the disease, and could be successfully used in the form of artificial culture to infect pigs with swine fever. This conclusion had to be abandoned when it was shown (1) that pigs which had recovered from an attack of the disease set up experimentally by this bacillus had no immunity against swine fever, (2) that when a pig was infected experimentally with this bacillus it did not pass the disease on to other pigs kept in contact with it, (3) that the blood of a pig affected with swine fever was capable of causing swine fever when injected into a healthy pig, although the so called swine fever bacillus was absent from it, and (4) that when the bacillus was present in swine fever blood the latter

remained infective, although this bacillus and any other visible organisms had been separated from it by filtration, or had been killed by the action of disinfectants.

This bacillus, therefore, is certainly not the cause of swine fever, but the great frequency, not to say absolute constancy, with which it makes its appearance in the blood in cases of swine fever is very remarkable. Moreover, although it is not the actual cause of swine fever, that is to say, not the organism which is handed on from diseased to healthy pigs when the disease is spreading naturally, there are strong reasons for believing that it plays an important part in the pig's illness. That, however, is a point that will be referred to again later.

The fact that the true cause of swine fever is invisible, and cannot be cultivated, places difficulty in the way of ascertaining precisely whether, and in what amount, it is present in the different parts of the body in cases of the disease. Nevertheless, a good deal of information with regard to these points has been provided by experiment. Although it is not exactly known where the virus multiplies at the outset, it has been shown that at a very early stage in the disease, and often before the pig becomes visibly ill, the virus appears in the blood, and that it continues to increase in amount there until the disease reaches its height. It follows from this that soon after the onset of the disease the virus is diffused throughout the whole of the organs and tissues of the body. It has also been ascertained by experiment that the virus may be present in the alimentary canal and in the urine—facts which are of importance in connexion with the spread of the disease.

Susceptibility to the Disease and Methods of Infection.

So far as is known, swine fever is a disease absolutely peculiar to the pig. Not only has the disease not been observed to occur naturally in any other species, but it has also been found impossible to transmit it by experiment to other animals than the pig. A contrary opinion was at one time held, but it was founded on the fact that rats, guinea pigs, and some other species could be infected by inoculating them with the so-called swine fever bacillus, which, as has already been shown, is not the cause of swine fever. It may be repeated here that the true cause of the disease is abundantly present in the blood at the height of the disease, and that, although the swine fever bacillus is then also often present, it may easily be separated by filtration. Such filtered blood or serum when injected into a susceptible pig sets up an attack of swine fever, and the pig thus infected will pass the disease on to healthy pigs placed in contact with it. On the other hand, large amounts of such filtered blood or serum may be injected into any of the small animals mentioned, or into any of the other domesticated animals, without any visible effect whatever.

Another important conclusion that appears to be fully justified is that the virus of swine fever is quite incapable of multiplying outside the body of a living pig in dirt, soil, or water, for example. That follows from the fact already mentioned, that the

virus has resisted all attempts to induce it to grow under laboratory conditions, however closely these have been made to imitate the conditions prevailing in soil, water, etc.

The facts just stated are important, for they warrant the further conclusion that the virus or material which infects any one pig must have escaped from the body of another pig previously attacked. And this leads to consideration of the ways by which the virus leaves the body of a pig suffering from swine fever.

All that can be said with regard to that is, that the urine, the fœces, and the discharge from the eyes have been proved to be infective, and that it is probable that matter coughed up and expelled from the lungs and air passages, and secretions from the skin may also contain the virus. It will be readily understood that from these different sources, but especially from the urine and fœces, an abundance of material capable of spreading the disease is always present in the immediate neighbourhood of a pig suffering from swine fever.

The most certain method of infecting a pig with the disease is to inject a dose (which need not exceed a few drops) of virulent blood under the skin, and next to that, to place diseased and healthy pigs in the same sty or premises. Feeding with blood, flesh, or other virulent materials is also generally successful in transmitting the disease experimentally, and it appears to be highly probable that the commonest method of natural infection is by swallowing the fresh excrement or urine of diseased pigs. Scraps of raw pork or bacon from diseased or unsuspected animals may be the cause of some outbreaks. It is also possible that infection may occur naturally by the inhalation of minute particles of fæces or other excretions suspended in the air.

In considering the manner in which the disease is spread, however, it is necessary to take account of other points besides the channels by which the virus enters and leaves the bodies of pigs. One of these is the question whether the virus is ever or frequently carried from place to place by men, or other animals than infected swine. This question has generally been given an affirmative answer, butchers, pig-dealers, and other persons who have been in contact with diseased pigs being thought capable of carrying the virus in an active condition on their hands, boots, or clothes. Rats have also been accused of carrying the disease from one sty to another. While it cannot be denied that the disease is ever spread in any of these ways, it may be said that infection by such indirect means is probably very rare. It has also been supposed that carts, railway waggons, etc., in which diseased swine have been carried may be dangerous. Opinion with regard to the extent of this danger has had to be modified in consequence of the results obtained in the experiments conducted for the recent Departmental Committee on swine in order to test the infectivity of litter or fœces in sties vacated by diseased pigs. These experiments indicated that when the fœces of diseased pigs or the litter soiled with their urine are left to natural influences they rapidly cease to be dangerous. As the point is of special importance, it may be stated that in these experiments infection succeeded when healthy pigs were placed

on the manure immediately after the diseased pigs had been removed, and in one experiment after seven days; but, on the other hand, negative results were obtained in experiments in which respectively one day, two days, fourteen days, twenty-one days, twenty-eight days, and forty-two days were allowed to elapse before the healthy pigs were placed on the infected manure. It can now be admitted that many thousands of pounds were until lately wasted annually in attempting to disinfect sties which would speedily have become harmless if left to themselves.

The matter may be summed up by saying that the commonest method by which the disease is contracted is direct contact with infected animals, and that beside this, all the other ways in which swine fever is spread sink into insignificance.

Symptoms and Course of the Disease.

Like all other contagious diseases, swine fever varies considerably in regard to the course which it runs. The severity of an attack depends upon a number of factors, the most important of which are the virulence of the infective material or virus, the dose or quantity of this virus, the age of the infected animal, and individual susceptibility.

That the ultra-visible virus, so to speak, varies greatly in its powers for mischief, is a fact which must be admitted, though it cannot yet be explained. It is to this cause that one ascribes either the exceptional severity or the exceptional mildness of the disease as compared with what is usually observed in pigs of the same age and breed, and kept under similar conditions. Young pigs are more susceptible than older ones, as shown by the severity of the symptoms and the greater proportion of fatal cases among them. The influence of varying doses of the virus is difficult to measure in natural cases, but it is observed in pigs infected experimentally by the injection of varying doses of the same virulent blood.

As a rule, the first discoverable evidence of infection, though it is hardly a symptom in the ordinary sense of the word, is a rise of temperature. The normal temperature of the pig varies between 102° and 103° F., and in swine fever it generally rises three or four degrees. This rise usually begins about a week or ten days after natural infection, but it may occur within four or five days, and even within two days, after inoculation with blood. This elevaton of temperature is not only the first discoverable evidence of infection, but also the most constant, since it may be detected in mild cases in which outward symptoms of actual illness are never exhibited.

Actual symptoms usually appear soon after, but sometimes accompany, the rise of temperature. They take the form of loss of appetite, dulness, an unwillingness to move, and an inclination to burrow into the litter if that is abundant. As a rule these symptoms become pronounced during the second week after natural infection, but they may appear earlier. Diarrhœa often, but by no means always, sets in, and in fatal cases there is rapidly increasing weakness, in consequence of which the animal sways in its hind-quarters when compelled to move. Thirst in

often manifested, although solid food is refused. Sometimes there is a diffuse reddish or livid discoloration of the skin from congestion of the cutaneous vessels. At any time during the period of visible illness an affected animal may develop a cough or begin to breathe rapidly, and these symptoms are usually the result of an attack of pneumonia, which is a comparatively frequent complication of swine fever.

What has just been said represents the train of symptoms usually observed in swine fever, but a fact which is of the greatest importance is that in quite a considerable proportion of cases, pigs which become infected develop no outward symptoms of illness. Even in such mild cases there is generally a more or less marked rise of temperature, but probably even that is sometimes absent.

The death rate among pigs which become infected may be anything from 95 per cent. down to 20 per cent., or even less. As a rule death does not occur in less than a week after the onset of symptoms, but it may happen within two or three days, and frequently it is deferred for several weeks if the disease is allowed to run its natural course.

In the animals that survive, the recovery is usually a real one, the lesions in the bowel and elsewhere healing up complet-ly, and the virus disappearing from the system. There are reasons for suspecting, however, that some animals make a recovery which is incomplete, with the result that, in spite of apparent health, they are capable of transmitting the disease, or acting as 'carriers.'

Lesions.

By the word lesions is here meant the alterations in the appearance and structure of the different parts of the body which are found in cases of swine fever. In very acute cases, especially in those in which death occurs within a day or two after the first signs of illness, the *post-mortem* examination may show no very pronounced abnormalties, or at least none that are at all characteristic. In such cases one expects to find diffuse inflammation of the stomach and intestines, especially of the large intestine, congestion of the lymphatic glands of the body generally, and small hœmorrhages in the kidneys, serous membranes, and other places.

In the immense majority of cases of swine fever, however, in which visible symptoms of illness have been exhibited for more than two or three days, a *post-mortem* examination will show lesions that are very distinctive in character. These lesions are found with greatest constancy in the large intestine, and especially in its anterior part. In the moderately acute cases, or in those killed at a comparatively early stage of the disease, one often finds that the large intestine is diffusely inflamed, and that the mucous membrane has adherent to it a whitish or yellowish material, somewhat similar in appearance to the membrane which forms in the throat in cases of diphtheria in the human subject. This type of disease in the intestines in swine fever is therefore called the diphtheritic type.

In most cases of swine fever, however, the lesions present at the time of death are of what is termed the ulcerative type. The so-called swine fever ulcers are rounded spots or patches, which usually vary in diameter from about ½-inch downwards, but in exceptional cases some of them attain a much larger size. These patches are in fact circular areas of the lining membrane of the bowel which have undergone necrosis, that is to say, the patch of tissue is dead or mortified.

In the condition in which they are most commonly encountered these lesions are thus, strictly speaking, not ulcers, but if a diseased pig survives for a sufficient time they become converted into genuine ulcers, owing to the shedding or casting off of the mortified piece as a slough. Whereas in the early stage the rounded patches generally stand a little above the normal level of the mucous membrane, the genuine ulcer produced by detachment of the slough is a shallow depression. In cases of actual recovery from swine fever these ulcers heal up, but for a considerable time afterwards their situation is marked by a smooth scar or depression on the lining membrane of the bowel. By the detection of such scars in the bowel one may recognize that a pig, apparently healthy at the time of slaughter, has some time previously suffered from an attack of the disease.

Although the bowel is the commonest situation of these ulcers, they are occasionally found in the stomach, on the tongue, and in the throat, and in very rare cases similar lesions have been observed on the skin.

Lastly, it ought to be said that not infrequently the diphtheritic and the ulcerative types of lesions are present in the same pig.

Other lesions which are not uncommon, though far less frequent than those just described, affect the lungs. The disease here takes the form of a pneumonia which tends to run its course rapidly, and lead to extensive consolidation of the lung tissue. Pluerisy often accompanies this pneumonia.

Reference must here be made again to the so-called swine fever bacillus, and to the part which it plays in the causation of the disease. As previously stated, pigs can be infected with artificial cultures of this organism, and in pigs so infected, lesions develop in the intestine which cannot be distinguished from those found in natural cases of swine fever. To explain this fact it appears to be necessary to assume that, although diphtheritic inflammation and ulceration are the most characteristic *post-mortem* signs of swine fever, these lesions are not produced by the ultra-visible virus which is the true cause of the disease, but by this swine fever bacillus, which plays the part of secondary invader. It may at first appear to be scarcely credible that an alteration which is so constantly present that it is generally relied upon as a guide to diagnosis in swine fever is not an essential lesion. It may be stated, however, that in this respect swine fever does not stand alone, there being a few other diseases in which the practically constant lesions are not set up by the actual cause of the disease, but by other bacteria which play the part of secondary invaders.

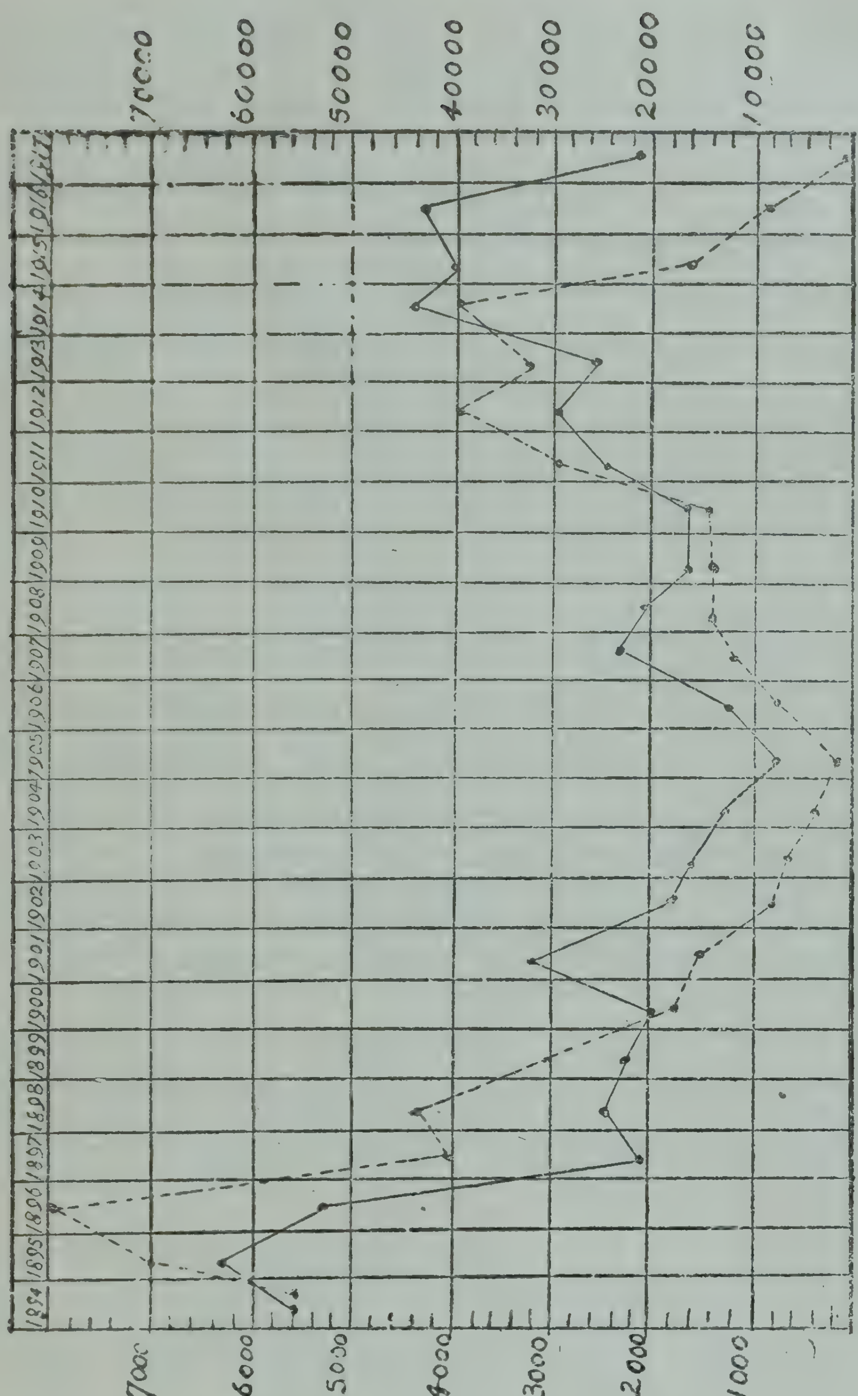
The so-called swine fever bacillus appears to be a common, if not constant, inhabitant of the intestines in the pig, and ordinarily it multiplies there to only a limited extent, does not invade the body, and therefore causes no disturbance of health. As a result, however, of the multiplication of the true virus of swine fever in the blood, the pig's resistance to infection with the bacilli from the intestine is weakened, and these begin to invade the intestinal wall, to cause inflammation and necrosis of the mucous membrane, and later on to invade the body generally to a greater or less extent.

Similarly, the evidence appears to show that the pneumonia which is so frequently met with in fatal cases of swine fever is not an essential or primary lesion, but is caused by another visible organism which is probably always present in the air passages of healthy pigs. The pneumonia which is caused by this bacillus was for many years described as an independent disease by many continental authors, and termed swine plague or contagious pneumonia of the pig. That this view was erroneous at least with regard to cases of pneumonia occurring among pigs in Great Britain, and that such pneumonia was generally, if not invariably, a mere complication of swine fever, was first pointed out by the Departmental Committee which investigated the subject in 1897.

Methods of Dealing with the Disease.

The Policy of General Slaughter.—At the end of October 1893, swine fever, which during the previous fifteen years had been dealt with by the local authorities, was taken in hand by the Board of Agriculture, and from that date until two years ago, it was opposed by measures ostensibly designed to stamp it out. During what may be termed the régime of the local authorities, the number of outbreaks reported annually varied from 1,717 in (1881) to 7,926 (in 1885). During the last complete year before the disease was dealt with directly by the Board, the outbreaks numbered 2,748. During the three years 1914 16 the confirmed outbreaks numbered 12,681, or an average of over 4,000 for each of these years.

The accompanying chart shows the fluctuations in the number of outbreaks from the beginning of the stamping-out system of dealing with the disease down to the close of the past year, and also the number of pigs slaughtered as diseased or exposed to infection during the period.



The continuous line shows the number of outbreaks in each year, and the dotted line the number of swine slaughtered in connexion with the outbreaks during the period 1894-1917. The values of the different points in the line denoting the outbreaks are indicated by the figures in the left, and those for the swine slaughtered, on the right.

It is beyond all argument that, in so far as the various swine fever orders have been framed with a view to the complete eradication of the disease, the action of the Board has been a complete failure.

It is unfortunately impossible to compare the number of outbreaks in the years 1879-92 with those for the period 1894-1917 in order to estimate to what extent, if at all, the outbreaks have been reduced since the disease has been dealt with by the Board. Such a comparison is impossible, because in the former period the outbreaks were 'reported', and in the latter 'confirmed'. At least in recent years the method of diagnosis has been both searching and uniform, and it may fairly be assumed that since 1907 the confirmed annual outbreaks give an approximately

correct measure of the prevalence of the disease. On the other hand, while the disease was dealt with by the local authorities, the methods of diagnosis were far from trustworthy, and the errors were mainly in the direction of including cases which had nothing to do with swine fever. An accurate comparison is also impossible because the obligation of owners to report has probably been better observed since 1893.

But when full allowance is made for these facts, it still appears not at all unlikely that the disease is as prevalent now as it was before the Board dealt with it directly. And it must be remembered that the failure has been a very costly one, even if one does not include the loss occasioned by the severe restrictions on the sale and movement of healthy pigs, which could never have been justified except on the prospect that they would lead to the stamping out of the disease.

There is room for difference of opinion as to whether the eradication of the disease was actually possible, or possible only at a cost exceeding the national loss which it causes, but there can be little doubt regarding the cause of the failure. The drastic plan of slaughtering all the pigs at any place where the disease had been diagnosed was a sure way of stamping out every discovered outbreak, and if this had been continued, and combined with proper restrictions on movement, the disease might have been finally extirpated. As the chart shows, however, this policy was not consistently followed, and for a number of years prior to 1915 the slaughter of all suspected pigs was not strictly enforced. Eradication may have been problematical before, but it became impossible under the altered system.

A share of the blame for failure may however be laid on other shoulders, for it is evident that even so-called cattle plague measures were bound to fail if in any considerable proportion of cases the existence of the disease was not promptly reported. That concealment was pretty frequently practised is scarcely open to doubt.

In conformity with the recommendation made by the Departmental Committee in 1915, the attempt to extirpate the disease by general slaughter has been abandoned 'for the present,' and probably no one saddled with any responsibility for the results will venture to advise its revival.

The Control of the Disease by the Use of Serum.

Before considering the part which serum treatment is capable of playing in attempting to control swine fever, it appears to be desirable to explain briefly the principal facts connected with the production of what are called 'anti-sera' in general.

As is well known, it is a general rule that when a man or an animal has recovered from an attack of bacterial disease, the person or animal in question is for a variable time afterwards more or less immune against a second infection with the same organism. Immunity which is acquired in this way is termed 'active'. In some cases it is possible to show by experiment

that this immunity depends upon something which has appeared in the animal's blood, and which continues to circulate there after recovery. Proof of this may be furnished by injecting some blood, or blood serum from the recovered animal into a normal non-immune animal of the same species, and immediately afterwards inoculating the latter with the bacteria which are the cause of the disease in question. Provided a large dose of blood or serum has been used in such circumstances, the experiment may show that in consequence of the injection the previously susceptible animal has acquired some immunity. The immunity obtained in this way is termed 'passive'. Knowledge of this fact would suggest that in practice one might use the blood of recovered animals for inoculating and immunizing healthy animals against various contagious diseases. This, however, is not practicable, because although the immunising substance occurs in the blood of animals that have recovered from a natural attack, it is never present there in any great amount, and consequently, too large a quantity of blood would have to be transferred to a healthy animal in order to give it protection. This difficulty, however, can in many cases be overcome by resorting to what is termed 'hyper-immunization'. In carrying this out one may select a full-grown healthy animal which already has some immunity in consequence of recovery from a first attack, and inject it subcutaneously or intravenously with a dose of the organism which is the cause of the disease. In all probability, in spite of the animal's immunity, the injection will provoke some considerable disturbance. When such disturbance has passed away the animal is given a second or larger dose of virus or bacteria, and this process is repeated many times, the dose of bacteria or virus being gradually increased. The effect of this procedure is to stimulate the production of the substance upon which immunity depends, and after a time, which may often have to be several months, the blood of the hyper-immunized animal becomes so enormously rich in the protective substance that only a small dose of it is required in order to immunize a healthy animal.

In the case of diseases that are caused by visible bacteria which can be cultivated artificially, cultures are naturally always used in the process of immunizing, that is to say, the animal is treated at intervals with steadily increasing doses of artificial culture. When, however, as is the case in swine fever, the cause of the disease cannot be cultivated outside the body, one has to use the fresh blood or other material from a diseased animal which is known to contain the virus in large quantity.

Finally, as a general point, it ought to be stated that the animal which is to be employed as a serum producer must be naturally susceptible to the disease against which the serum is to be used, for if an animal already possesses natural immunity against a given disease, injection of the bacteria of that disease into its body will not cause it to manufacture any protective substance.

Turning now to the particular case of swine fever, it may suffice to say that the serum is obtained from selected healthy pigs, which are given successive doses of virulent swine fever blood. At a place where serum has to be produced on a large

scale it is therefore necessary to have a constant supply of such blood, and in order to provide it relays of pigs are infected with swine fever, and bled to death when the disease is at its full height.

Unfortunately no other animal can be used for the purpose of providing infected blood, because, as already mentioned, the pig is the only animal known to be susceptible to swine fever.

The fundamental facts with regard to the powers of the serum are (1) that when given in sufficient dose to a healthy pig it renders the animal highly immune to swine fever for a time, (2) that this immunity steadily declines, and is so diminished as to be of no practical value after about ten days, (3) that the serum may be successfully employed to prevent the development of the disease, or to make the resulting attack non-dangerous, if it is given within a few days after infection, (4) that the serum is of no value for curing the disease in a pig that is already seriously ill.

It will be obvious that it is not advisable to use serum for pigs that are known to be healthy, and are not likely to be exposed to any risk of infection, for the immunity conveyed by the serum soon disappears. On the other hand, the serum may be used with advantage for the apparently healthy pigs on premises where the disease has already shown itself, and also for healthy pigs when there are strong grounds for fearing that some of them may have caught the infection.

Towards the end of September 1915, when the policy of attempting to stamp out the disease by slaughtering all diseased and suspected pigs was abandoned, serum was introduced by the Board as a means of dealing with out breaks. In outline, the plan now followed is as follows :—

All Veterinary Inspectors are provided with a supply of serum from the Board's laboratory. When the Board receives intimation that swine fever is suspected to exist at any place, the nearest Veterinary Inspector is instructed to visit the premises and make a diagnosis, taking with him a reasonable supply of serum. Should he diagnose swine fever, he is authorized to carry out treatment with serum if the owner agrees, without waiting for confirmation of his diagnosis by the Board. Meanwhile parts from some of the suspected pigs are sent on to the Board's laboratory, and when the Veterinary Inspector has in the first instance reported that disease did not exist, and this opinion is found to have been incorrect by the investigation at the laboratory, the Inspector is immediately instructed to re-visit and offer serum treatment.

The acceptance of serum treatment by the owner is at his option. When he accepts, and the treatment is applied to all or a portion of his pigs, he is advised to allow the healthy pigs treated on the infected parts of the premises to mix with the affected pigs, in order that the former may become infected by contact while still under the influence of the serum. As the immunity conveyed by the serum only lasts for about ten days, after which the pigs again become susceptible to swine fever in a fatal form if they have not previously become infected by contact, the

only alternative to allowing the treated pigs to mix with the ailing is to give repeated doses of serum until all the ailing are dead or recovered. That, however, is not resorted to except when large numbers of healthy pigs are suspected, and it is impossible to bring about proper mixing between the diseased and the healthy.

After the administration of the serum, Veterinary Inspectors pay periodical visits to the outbreaks, and report as to the condition of the pigs.

Healthy pigs may by licence be moved off infected premises for immediate slaughter, and other pigs may be moved on for fattening purposes, the latter being usually treated with serum on arrival. The owner is thus able to continue his pig feeding qusiness although infection may be present on his premises.

It is important to observe that no ailing or suspected pigs are slaughtered or compensated, for except such as are destroyed by the Veterinary Inspector in order to enable him to arrive at a definite diagnosis by *post-mortem* examination.

Furthermore, in considering what follows the acceptance of serum treatment by an owner, it must also be noted that when the treatment is refused, restrictions on the movement of pigs to or from the infected premises are imposed, and the owner is simply given the option of allowing the disease to run its course, or to slaughter his pigs for the market at his own risk.

Whether serum treatment is accepted or refused, the restrictions on the movement of pigs to or from the infected premises are maintained until in the opinion of the Board the disease has ceased to exist there.

Information with regard to the results of the serum treatment for the past year have not yet been published, but apparently during the year after its introduction (September 1915) only about half the owners on whose premises swine fever was diagnosed agreed to the use of serum. * During this period the treatment was applied to 2,100 outbreaks, in which 77,900 pigs were involved, and when the results were compared with those obtained in outbreaks in which serum was not used, it appeared that there was a marked advantage in the employment of serum.

It cannot be claimed that it would be to the advantage of every owner to agree to the serum treatment, for when the disease has been diagnosed, and the surviving apparently healthy pigs are of the proper age and condition, it will probably always be best for the owner to slaughter out for the butcher, and after a brief interval re stock. When, on the other hand, the infected herd includes valuable breeding animals, or stores of various ages that are not yet fit for the butcher, he will be well advised to decide in favour of the serum treatment.

It must be admitted, however, that there are unsolved difficulties in the treatment of outbreaks in which the herd already includes sucking or recently weaned pigs, or sows that

*Annual Report of the Chief Veterinary Officer for the year 1916.

are due to farrow within the next month or two, for hitherto the mortality among very young animals exposed to infection has been very serious (up to 25 per cent.) in spite of serum treatment.

A very serious handicap to the serum treatment of outbreaks, and indeed to any method of dealing with the disease, is that in very many cases the infection has already spread to a considerable proportion of the pigs on the premises before the suspected existence of the disease is reported. How injuriously this affects the results will be understood, when it is remembered that the serum is useless as a curative, and apparently of very little value in the case of animals that are near the end of the period of incubation. Experience so far has indicated that, on an average, about 30per cent. of the pigs still alive are in this more or less hopeless condition before the serum is injected. As the remedy for this is entirely in the hands of owners, the advantage to themselves of prompt reporting cannot be too strongly emphasized.

A suspicion of swine fever should always be entertained when any new pigs have been recently brought on to the premises. If possible, such animals ought to be isolated for several weeks, and inspected daily for signs of ill health. The critical period is the second week after arrival, but, of course, the disease may show itself before that. The owner should remember that it is not the existence of swine fever, but the suspicion of it, that he has to report, and that when recently purchased pigs appear ailing, it is better not to wait for what he may consider the decided symptoms of the disease.

There remains to be mentioned a method of employing serum which is different from the one just described. This consists in inoculating pigs simultaneously with serum and with virulent blood. What is expected from this operation is that the attack of swine fever caused by the virulent blood will be held in check by the serum, with the result that the disease will be mild and non-dangerous, but will leave a strong and lasting immunity. Unfortunately this result is not obtained in every case, and although the losses caused by the operation itself vary greatly, they probably cannot be placed at less than 5 per cent., on an average, among pigs under six months old. This method has been practised on a very large scale in the United States of America and in Hungary – countries in which the swine fever is already so diffused, and the facilities for the spread of the infection are so great, that the stamping out of the disease or even its control by restrictions on movement is considered impossible. It will be readily understood that in such circumstances, the best plan may be to encourage every owner to have the whole of his pigs systematically vaccinated by the above method, as soon as they reach a suitable age. It will be equally plain that the method has at present no interest for this country, as if generally practised it would occasion a loss far in excess of what swine fever has caused in the worst years.

THE IMPROVEMENT OF THE YIELD OF SEA ISLAND COTTON IN THE WEST INDIES BY THE ISOLATION OF PURE STRAINS.

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INTRODUCTION.

Since the year 1903, when the Sea Island cotton industry was first started in the West Indies, attempts have been made by the agricultural officers in the various islands to obtain varieties suitable for their own special conditions, and also to maintain the standard of quality of the lint at as high a level as possible. The method followed by all workers concerned was essentially the same in principle. Certain plants were selected in the field for good vegetative characters. After this the lint and seed characters were examined in the laboratory, and finally the best were chosen for planting in progeny rows. In the next year the best were again chosen, and the same procedure followed, so that the final result has been that in St. Vincent, St. Kitts, Montserrat, and Antigua, the general appearance of the plants in field crop is now remarkably uniform, and there is a notable freedom from the inferior hybrids of Upland origin which were frequently seen in the first years of the industry. In short, the effect of the method followed has been not only to render the crop far more uniform than when it was first grown, but the elimination of inferior types has led to a marked improvement in the quality of the lint—an improvement which is reflected in the high prices which the spinners are willing to pay for it.

Incidentally each island has had its own problems to face. In St. Vincent the yield has never been altogether satisfactory from the point of view of the planter, and efforts have been made to overcome the lowering effects of cryptogamic disease on yield by the selection of higher yielding and resistant varieties. In Montserrat a good deal has been done to improve the quality of the cotton. Montserrat has been discriminated against in the past on account of the relatively coarse nature of its cottons, but Mr. Robson has shown that cottons of very fine quality can be grown in that island. In Antigua, besides endeavouring to improve the quality of the lint, efforts have been made by the Agricultural Department to produce a type which will yield well on the heavy soils of that island.

It will be seen that the system of selection so far followed is the same in principle as the Vilmorin system of pedigree selection, which is used extensively, and with great success at the famous plant breeding station of Svalof in Sweden, in connexion with the improvement of cereal crops. This principle of making

use of the single plant as a starting point for superior races had been applied many years before by Le Couteur and Patrick Sherrif, of England.

The weak points in the West Indian method have been that until recently very little attempt has been made to determine statistically how far the various strains were pure for the character selected, and also that the frequent contamination by cross-fertilization was not taken into account.

The work of Dr. Lawrence Balls ([1], [2], [3],) in Egypt in the production of pure strains of Egyptian cotton has led West Indian workers to realize that the accumulation of statistical data in regard to the various characters studied, and also the protection of the strains worked with from cross-fertilization must form an essential part of the work of cotton breeding.

In the opinion of the present writer the time has come when it will be of use to indicate the progress which has so far been made in isolating pure strains, particularly in St. Vincent; to discuss the methods which it seems advisable to follow in future; and lastly, to state what progress may be expected from the adoption of these methods.

At the outset we may state that the work of cotton improvement must always bear a dual aspect. On the one hand, the quality of the lint must be satisfactory to the spinner; on the other hand, the planter naturally desires to obtain the largest profit from his land. From the planter's point of view the matter may be represented schematically as follows:—

Maximum value of lint per acre.

- Value of lint per lb.
- Pounds of lint per acre.
  - Number of bolls per acre.
    - Number of bolls per plant.
      - Depends on a large number of factors: resistance to shedding, prevalence of insect pests, fungoid disease, habit of plant, fertility of soil, etc.
    - Number of plants per acre.
  - Weight of lint per boll.
    - Number of seeds per boll.
      - Number of loculi per boll.
      - Number of seeds per loculus.
        Number of ovules per loculus.
    - Weight of lint per seed.

It will be seen that the yield of lint per acre depends on a large number of factors, morphological and physiological. It is by the interaction of these factors at their optimum that the highest yield is built up. The failure of any one factor to co-operate efficiently tends to lower the yield. For example, if the weather conditions are unfavourable—if there is too much or too little rain—then the number of bolls per plant is reduced by shedding, and the yield is immediately lowered. So also, if the weight of lint per seed is zero, the yield is zero. Bearing in mind that yield is, in the West Indies, primarily dependent on weather conditions, it is a matter of importance to make a thorough study of the morphological and physiological characters which affect yield. Weather conditions cannot be controlled, but at least an endeavour can be made to produce a variety the hereditary endowment of which will interact with environmental

conditions to the best advantage. The comparison of different strains in respect of their yielding capacity must necessarily prove an extremely difficult task. Let us consider two hypothetical strains. One strain (A) may be characterized by a high weight of lint per boll, and possess great liability to shedding in an unfavourable season. Another strain (B) may have a low weight of lint per boll, but possess comparative resistance to shedding. In a favourable season A would be the heavier yielder, because shedding would be a negligible factor: in an unfavourable season B would be the higher yielder, for its resistance to shedding would more than balance the higher weight of lint per boll of A. In short, the effect of many morphological factors affecting yield may be totally obscured by environmental conditions. It is clear that the most logical method of improving yield must be to determine, firstly, what is the range of variation existing in Sea Island cotton in respect of the morphological characters concerned; secondly, to isolate strains with the highest maxima; and thirdly, to produce strains possessing the best combination of morphological characters consistent with a high-grade lint. At this point it may be stated that we do not know at present whether cottons are possible possessing a combination of superfine quality and a high weight of lint per seed. It may be that the two are incompatible, but it would be unsafe to dogmatise on the point and say that a superfine cotton must necessarily have a low ginning outturn, a low weight of lint per seed, and possess a more delicate constitution than ordinary Sea Island. All these points have still to be investigated.

None of the questions raised in this paper have been gone into thoroughly. Certain general conclusions may, however, be drawn from the data which have been obtained. The conclusions of Balls ([1], [2], [3]) in regard to the composition of Egyptian cotton are broadly true of Sea Island cotton also, i.e., Sea Island cotton consists of an enormous number of types which are different both physiologically and morphologically. By self-fertilization and selection, strains pure to any given character can be obtained, and it is certain that the method of pedigree selection is capable of yielding rich results in a comparatively short period, if the work can be conducted on a large enough scale.

Methods of Work.

In the work conducted by the present writer it was seen from the outset, that the best field for progress lay in the following out from generation to generation of certain selected characters, in order to see what would be the effect on them of continued selection. In the study of any character affecting yield, such as the weight of lint per seed, data were obtained from as many cottons as possible, and a certain number, say, five or six with the highest values, were selected for growing in progeny rows. On the progeny rows coming to maturity every plant was examined for the character, and a frequency array compiled. From the row possessing the highest mean value, a few of the highest were again selected, to be studied in the next generation. This process is to be continued until it is clear that the upward

limit of the character has been reached, i.e. until the progenies of all plants in the parent strain show the same means. When this stage is reached, it will be evident that the strain is pure in regard to this one character. It may of course be impure for other characters, and if necessary, the process of purification can go on until the strain is pure for all visible characters.

All the plants worked with are self-fertilized. After trying various methods, the expedient was adopted of tying up the end of the unopened flower bud with a piece of string. The most suitable time is in the early morning before opening takes place. In the afternoon the tied flowers are examined, and those that have not forced off the string are tagged with coloured wool. In practice this re-examination has been found to be necessary when the work is done by ordinary women labourers. This method has been found to be more efficient than the wiring method, and it has, besides, the advantage of cheapness.

Ovules and Seeds per Loculus.

In discussing this question it will be convenient to begin with an examination of a series of data taken from a single plant. This will be found below.

	No. of loculi in boll.	Plant G. × S.I.										Readings.	Mean.	Probable error of 1 observation.
		01	2	3	4	5	6	7	8	9	10			
Ovules...	4							34	58			92	7·6±·03	± ·30
	3							8	59	7	1	75	8·0±·04	± ·34
Seeds ...	4	24	3	4	15	9	21	32	19	2		111	5·8±·15	±1·47
	3	12	3	2	4	4	10	18	13	6		63	6·2±·19	±1·46

From the above table the following conclusions may be arrived at :—

1. The number of ovules per loculus is greater in bolls with 3 loculi than in bolls with 4 loculi, by 5·3 per cent.

2. The number of seeds per loculus is greater in 3-locked bolls than in 4-locked, by 5·2 per cent.

3. The variation in seeds per loculus is greater than that of ovules per loculus.

It will be seen that there is a certain loss. All the ovules do not produce good seeds, and therefore from the point of view of yield must be regarded as a dead loss. The loss is summarized below :—

Per cent. loss in 4-locked bolls ...	...	23·7
Per cent. loss in 3-locked bolls ...	...	21·3

That is, the number of ovules maturing into seeds which bear lint is slightly greater in 3-locked than in 4-locked bolls. The number of seeds per boll in 4-locked bolls is twenty-three; in 3-locked, nineteen. In data taken from a large

number of bolls from the Sea Island manurial plots the mean weight of lint per seed for 3-locked bolls was 43mg. on 3,059 seeds, and for 4-locked bolls 42mg. on 520 seeds. For practical purposes it may be assumed that there is no difference in the weight of lint per seed in bolls with different loculi. Accordingly, it appears that in this particular plant a 4-locked boll is superior to a 3-locked boll in respect of lint per boll, by about 12 per cent., and it may be concluded that it is advantageous to have a high number of loculi per boll. This point, however, will be discussed in detail at a later stage.

Data have also been recorded from a number of other types of cotton. Some have been examined for ovules per loculus, some for seeds per loculus, others for both. The results are presented in Table I below.

Table I.

SHOWING VARIATION IN NUMBER OF OVULES AND SEEDS PER LOCULUS IN DIFFERENT TYPES OF COTTON.

Frequency array of ovules or seeds per loculus.

Variety.	Ovules or seeds.	Loculi.	0	1	2	3	4	5	6	7	8	9	10	11	Number of readings.	Mean.
Single Plant H I.	Ovules	4							6	49	28	1			84	7·3
do.	do.	3								34	51	5			90	7·7
Single Plant S.V.N.C.	do.	4								10	18				28	7·6
do.	do.	3									15	6			21	8·3
do.	Seeds	3&4													200	4·9
Upland Row	Ovules	4									3	49	61	7	120	9·6
do.	do.	5								1	2	35	17		55	9·2
Upland Single Plant	do.	4&5								1	4	74	57	5	141	9·4
do.	Seeds	do.							1	1	4	7	25	21	59	8·6
G.S.I. 12 Single Plant	Ovules	3&4							4	13					17	6·8
do.	Seeds	do.	11	9	18	15	5	4	2						64	2·2
Sea Island Row	do.	3		11	19	57	205	511	828	359	30	2			2022	5·6±·02
do.	do.	4		2	5	8	47	84	87	49	3				285	5·4±·05
Sea Island Poor conditions	Ovules	3&4						26	47	11					84	5·8
do. Very poor conditions	do.	do.						14	9	1					25	5·5
Cauto Row	do.	3									6	94			100	8·9

From the above table the conclusions drawn from the study of a single plant can be verified, and in some degree amplified. It seems that in general there is a certain reduction in the number of ovules per loculus as the number of loculi becomes greater. In spite of this reduction, it is seen that in a type like the Upland variety recorded above, a 4-locked boll would contain thirty-eight ovules, while a 5-locked would contain forty-six. Thus, if the percentage of ovules maturing into seeds, and the weight of lint per seed remain the same whatever the number of loculi, the desirability of a maximum value for this character is abundantly clear. The number of ovules per loculus is constantly greater in Cauto than in Sea Island, and greater in Upland than in Cauto. Thus, this character is definitely specific, and it becomes necessary to find out what variation occurs in Sea Island, and whether it is possible to isolate strains with higher values than those now grown.

A further point is brought out by Table I. It was seen that in plant G × S. I. a certain number of ovules failed to mature into seeds. From Table I it is apparent that in all cottons there is a loss, but that the loss is much greater in some strains. Thus, for a single Upland plant the loss was 8·5 per cent.; for plant G × S. I. it was 67·6 per cent. A careful examination of the floral structure of the latter plant did not throw any light on the reason for the abnormal loss. The plant was in the F_2 of a cross between Upland and Cauto, both of which have in general a high percentage of seeds to ovules. In certain Sea Island strains a large number of green specks can be noticed in the seed-cotton. These are ovules which have failed to develop, either through failure of pollen to reach the stigma, or possibly owing to the presence of some degree of self-sterility. Other strains produce very few undeveloped seeds, and these strains are usually characterized by a high number of seeds per loculus. Data for ovules per loculus of the Sea Island pedigree selections are not available, but a large number of plants were examined for seeds per loculus. The results are presented in Table II.

Table II.

SEEDS PER LOCULUS OF SEA ISLAND STRAINS.

Frequency array seeds per loculus.

Family.	0	1	2	3	4	5	6	7	8	9	10	No. of readings.	Mean.
V. 1. 9. 37 ...	–	2	11	22	61	122	239	279	54	5	–	795	6·0
V. 1. 9. 27 ...	–	1	6	11	23	63	142	115	13	1	–	375	5·9
V. 1. 9. 22 ...	–	3	12	23	81	198	308	184	17	–	–	826	5·7
V. 1. 9. 7 ...	–	–	2	–	11	15	38	29	5	–	–	100	5·9
V. 3. 32. 3 ...	–	–	1	2	6	18	42	25	6	–	–	100	5·5
V. 5. 61. 18 ...	–	–	3	3	6	17	55	14	2	–	–	100	5·7
V. 5. 61. R1. P1. 8	–	–	–	3	5	15	45	28	4	–	–	100	6·0
V. 5. 56. 28 ...	–	–	–	1	6	20	33	30	10	–	–	100	6·2
V. 1. 9. 19 ...	–	4	5	13	30	77	175	153	39	–	–	496	6·0
V. 1. 9. 35 ...	–	3	6	21	53	132	228	186	17	–	–	646	5·8
V. 5. 56. 34 ...	–	–	3	14	19	47	108	147	47	1	–	386	6·3
V. 5. 61. 24 ...	–	6	11	26	73	214	452	125	5	–	–	912	5·6
V. 5. 56. 33 ...	–	–	6	8	29	66	153	134	17	2	–	415	6·0
$\frac{13}{43}$ 1. 20. ...	–	5	20	38	117	169	155	66	5	–	–	575	5·1
$\frac{13}{43}$ 1. 18 ...	–	7	13	32	71	128	108	15	–	–	–	374	4·8
B. S. 1. 53 ...	–	–	5	16	39	101	244	279	23	–	–	707	6·1
B. S. 1. 33 ...	–	1	9	21	46	77	175	161	14	–	–	504	5·8
G. S. 3. 5 ...	–	–	–	4	5	21	39	29	2	–	–	100	5·9
G. S. 3. 14 ...	–	–	1	3	10	27	32	25	2	–	–	100	5·7

The main conclusions from the above table are as follows :—

1. Strains of Sea Island cotton differ in mean number of seeds per loculus. It is not known whether this is due to specific differences in the number of ovules per loculus, or to differences in the percentages of ovules which mature. Strains $\frac{13}{42}$. 1. 18 and $\frac{13}{42}$. 1. 20, both of the parentage, possess a very low value for seeds per loculus, and are characterized by an abundance of green undeveloped seeds with no lint.

2. The importance of the number of seeds per loculus as a factor concerned in yield is considered to be adequately demonstrated. An attempt will be made to see whether strains with still higher mean values can be isolated by selection.

Lint Index and Lint Percentage.

Some discussion has taken place respecting the relative importance of lint index and lint percentage as factors in cotton selection. Cook (4) in 1908 pointed out the danger of laying two much emphasis upon the percentage of lint, and advocated the substitution of lint index (weight of lint per 100 seeds) as a character for selection. One of his reasons is that very high percentages of lint are usually associated with small seeds, and he argues that large seeds are advantageous since they contribute to the prompt developement of the cotton by giving the young plant a better start. He cites the case of a small-seeded variety, the Peterkin, which sometimes fails to come up. Large-seeded types like the Russel may show a good stand under the same conditions. This attempted correlation between large seeds and vigour involves a biological fallacy. No proof of such a correlation has been advanced.

Johannsen (5) has shown that different pure lines of beans possess their own specific mean seed weight. It would not be difficult to show that the same is true of cotton. The writer has isolated a Sea Island strain breeding true to a very small seed weight, and other strains with much larger seed weights. Careful examination of the small-seeded and large-seeded strains has failed to reveal any constant differences in vigour or in ability to produce a good stand. In a strain pure to a given seed weight, it is undoubtedly true that a better stand is given by the heavier seeds. This is however partly due to the elimination of non-viable seed. A distinction has to be made between seeds which are heavy through fluctuation, and those which are heavy because they belong to a strain which is genetically heavy.

So far as Sea Island cotton is concerned, the writer finds himself in complete agreement with Cook (4) in regard to the small importance to be attached to lint percentage as a factor in yield. It is plain that the weight of lint per seed is one of the most important of the morphological characters affecting yield, whereas lint percentage has no bearing on yield except in so far as a high lint percentage is correlated with a high lint index. In regard to the question of small *versus* large seeds, a large seed is obviously more desirable, for its potential lint-bearing surface is so much greater. If the maximum lint index is obtained, it will probably be found in association with a very high seed weight

The results of the examination of various strains of Sea Island cotton for weight of lint per seed will be found below in Tables III a and III b.

Weight of lint per Seed in Milligrams. / Family	V.1.9	V.1.9.7	V.1.9.19	V.1.9.22	V.1.9.27	V.1.9.35	V.1.9.37	V.5.61	V.5.61.18	V.5.61.24	V.5.61.R	V.5.56	V.5.56.33	V.5.56.34	V.3.32	V.3.32.3
31											/					
32											–					
33											–					
34											/					
35					/						–	/				
36					–			2	/		–	–				
37					–	/		/	–		–	/			/	
38		/			2	–		–	2		–	/			2	
39		2			/	–	/	–	–		–	/			/	
40		–			2	–	–	2	/	2	–	–			2	
41		–			–	/	/	–	/	2	/	/		/	–	
42	+/	2		/	×5	2	/	3	4	/	/	+ × –	2	–	2	
43	2	+2		2	+2	–	/	×2	×–	4	2	–	2	/	×/	
44	/	×/		3	–	–	2	–	3	2	2	/	–	/	2	/
45	–	2	2	3	–	3	×/	2	/	4	× +3	–	/	/	+/	–
46	×/	/	2	3	/	×4	+6	2	4	×4	/	–	×–	/	4	3
47	/	/	/	× +/	/	–	–	3	3	+3	/	–	2	×/	2	+2
48	/	2	–	–	–	3	–	+	/	4	/	/	+–	3	/	2
49	2		×3	/	–	+2	2			2	/	–	2	2		/
50	–		–	4	/	–	–			2	–	/	2	+/		×–
51	/		+3	/	–	–	–			–	–					2
52			–	/	/	–	/			/	/					2
53			/	/		/				/	–					/
54				–							–					/
55				/							–					–
56											–					2
57											–					
58											/					

+ = *Parental value.*

× = *Mean of strain*

Weight of lint per seed in Milligrams. / Family	B.S.1.	B.S.1.33	B.S.1.53	B.S.5	B.S.6	B.43.1	B.43.1.18	B.43.1.20	B.43.2
26			/						
27			—						
28			—		2				
29	/	+ —	—		—				
30	/	—	+ /	3	×/				
31	—	—	—	3	2			/	
32	—	—	/	/	2			—	
33	—	—	2	—	2			/	
34	—	2	2	6	×2			—	
35	× —	/	×2	+×4	3			—	
36	—	×3	2	7	+/			—	
37	—	—	3	4	4	/		/	/
38	—	—	—	2	/	—		—	—
39	/	—	/		/	2		—	—
40	—	—	—			/		—	/
41	—	—	—			/		/	—
42	—	/	/			6		2	—
43	+/					×/	/	/	×/
44						+/	2	6	/
45						4	/	×/	/
46						/	2	2	/
47						—	× —	/	/
48						—	—	2	
49						—	/	2	
50						—	2	—	
51						/	—	+3	
52						/	+ —	—	
53							/	/	

+ = *Parental Value.*

× = *Mean of strain.*

The main conclusions arrived at by a study of the weight of lint per seed in Sea Island cotton are as follows :—

1. In the first year of selection the six plants with the highest weight of lint per seed obtainable had values in milligrams, respectively, of 53, 49, 48, 45. Many hundreds of plants in field crop were examined.

2. In the third year of selection forty-four plants out of a much smaller number had a value of ·50 or over, so that selection in the first place has had the effect of increasing the number of plants with high values.

3. One strain in V.3.32.3. has the very high mean value of 50.

4. Some strains have a much smaller range than others. Note the extraordinary family, V.5.61.R., which ranges from 31 to 58.

5. It would appear that the B.S. families Nos. 1. 1.33, 1.53, 5, and 6, are incapable of throwing any plant with a higher value than 43. All these families have a mean of 34, 35, or 36. Selection amongst the other types does not appear to have produced any family pure to the highest maximum value, and it is intended next season to effect a further purification. What is of paramount importance is that this character is undoubtedly genetic, and that different strains are characterized by different values.

In regard to lint percentage, there is little to be said of consequence, for as already pointed out, it is not regarded as of importance in breeding work. The normal percentage of lint to seed in ordinary Sea Island cotton varies from 25 to 27 per cent., with a lint percentage of about 31. The following are the data concerning this strain :—

1916. Plant V.2.21 had a lint percentage of 31·6, with a mean seed weight of 97 mg., and a mean lint weight of 45 mg.

1917. Thirty plants were grown in progeny row. The seed weight ranged from 80 to 103 mg. The mean weight of lint per seed ranged from 35 to 50 mg. The mean lint percentage for the strain was 31.

1918. A plot of 106 plants was grown from one of the 1917 plants. The range in seed weight was 70 to 103 mg., in lint weight 32 to 54 mg. The mean lint percentage was 33·3 per cent.

Thus, it is evident that it is easy to isolate, from a mixed Sea Island population, strains with a much higher lint percentage than normal. This particular strain is a chance combination of a fairly high weight of lint per seed—44 mg.—and a very low seed weight of 88 mg. This cotton does not possess any advantage over ordinary Sea Island, but it is certainly not less vigorous in growth, in spite of its small seeds.

Number of Loculi per Boll.

This character has already been alluded to in the discussion of seeds per loculus, and the view was expressed that it is desirable to select for a high percentage of 4-locked bolls.

The Sea Island boll may have 3, 4, or 5 loculi. On some plants bolls with all three numbers are present. On others occur bolls with three and four only. The proportional numbers of the two or three kinds of bolls are, on the whole, constant for any one plant. Since strains in two different seasons are to be found possessing a constant mean value for this character, the proportions in which the different numbers occur is presumably a matter of genetic constitution. The question whether there is any particular effect of soil conditions upon this character is of importance. A plant was grown under very poor soil conditions. In fifty bolls there were ten which were quadrilocular. A bud was taken from this plant and inserted in a plant of the same strain growing in better soil. The number of quadrilocular bolls in fifty was raised to twenty. This experiment tends to show that poor soil conditions tend to reduce the mean number of loculi per boll.

In Egypt, Balls ([3]) studied the inheritance of this character. He found that in certain crosses the parental forms could be extracted in F_2 and some bred true in F_3, while the forms with higher values were also produced. Thus from a cross between a 4·3 and a 3·0, there was obtained a 4·8 which bred true in F_3.

In the examination of this meristic character, the mean number of loculi per boll is calculated from the results of forty bolls taken at random from each plant. At this point it will be of interest to present a set of data illustrating the hereditary nature of the mean number of loculi per boll.

Table IV.

ILLUSTRATING THE HEREDITARY NATURE OF THE MEAN NUMBER OF LOCULI PER BOLL.

		a	b	c	d	e	f	g	h	i	j	k
Mean number of loculi per boll.	3·4		1			1						
	3·5		2			–						
	3·6		8	3	1	3	1	4				
	3·7		6	4	+2	4	+1	12				
	3·8		1	5	2	+7	4	6				
	3·9	1	2	+3	1	2	4	+2				
	4·0		2	1			1				5	
	4·1									1	6	1
	4·2								1	9	7	4
	4·3									3	+12	+8
	4·4										8	
	4·5										3	
	Mean ...		3·7	3·7	3·7	3·7	3·8	3·7		4·2	4·2	4·2

+ = parental value.
a. A plant of a native cotton found in St. Croix.
b. Progeny of a.
c. Progeny of one plant in b.
d. ditto.
e. Progeny of a plant in c.
f. ditto.
g. Progeny of one plant in d.
h. A plant of the Upland variety Southern Cross.
i. Progeny of h.
j. Progeny of a single plant in i.
k. ditto.

From Table IV it is clear that for three generations the two types, St. Croix native and Southern Cross, have preserved their specific values for the number of loculi per boll. The former variety has a mean value of 3·7, the latter 4·2.

Table V shows the results of the examination of certain Sea Island strains for mean number of boll loculi.

Table V.

RESULT OF THE EXAMINATION OF SEA ISLAND STRAINS FOR MEAN NUMBER OF LOCULI PER BOLL.

	V. 1. 9.	V. 1. 9. 7.	V. 1. 9, 19.	V. 1. 9. 22.	V. 1. 9. 27.	V. 1. 9. 35.	V. 1. 9. 37.	V. 5. 61. 18.	V. 5. 61. 24.	V. 5. 61. R.	V. 5. 56. 33.	V. 5. 56. 34.	V. 3. 32.	V. 3. [illegible]	B. S. 1. 33.	B. S. 1. 53.	13. 43. 1.	13. 43. 1. 18.	13. 43. 1. 20.	13. 43. 2.
3·0									1							2				
3·1		2						5	11	3	1	1			+8	+8	11	+3	4	
3·2		3	1	1				+8	+14	7	+4	4	1	11	4	8	+1	3	7	+
3·3		4	1			1	1	7	5	+2	3	+4		3	1	3	5	6	+5	3
3·4		2	3	2	3	1	1	7	2	1	3	3					2		5	3
3·5	1	1	1	4		1	+1	2		1	1						1		2	1
3·6		+	+1	+1	+3	+3	4	1												
3·7			6	2	3	7	6													
3·8			1	1		5	5													
3·9			1	3																
4·0					1	1														
Mean.	·	3·3	3·6	3·6	3·6	3·7	3·7	3·3	3·2	3·2	3·3	3·3	·	3·2	3·2	3·2	3·2	3·2	3·2	3·4

+ = parental value.

The following conclusions may be drawn from the above table :—

1. In the Sea Island strains examination there are two races differing in the mean number of loculi per boll. One race has a mean value of 3·2 or 3·3, and the other a value of 3·6 or 3·7.

2. It may be suggested that families V.1.9.37, and V.1.9.35, are pure for the higher value, while V.1.9.7, 13.43.18, and 13.43 20 are apparently pure for the lower.

3. The most important feature of these results is that by selection the percentage of 4-locked bolls has been increased from 20 (the value for ordinary Sea Island) to 60 or 70.

Comparative Value of Sea Island Strains.

Having discussed the various morphological characters which have to do with the yield of Sea Island cotton, it is now

expedient to assess the comparative value of the strains so far produced. All these characters bear on one point—the weight of lint per boll. The results of such a comparison are set out in Table VI below.

Table VI.

SHOWING A COMPARISON OF VARIOUS SEA ISLAND STRAINS IN REGARD TO MORPHOLOGICAL FACTORS AFFECTING YIELD.

Family.	Mean seeds per loculus.	Mean weight of lint per seed in mg.	Mean loculi per boll.	Weight of lint per boll in gms.
V.1.9.7 ...	5 9	44	3·3	·86
V.1.9.19 ...	6·0	49	3·6	1·06
V.1.9.22 ...	5·7	47	3·6	·96
V.1.9.27 ...	5·9	42	3·6	·89
V.1.9.35 ...	5·8	46	3·7	·99
V.1.9.37 ...	6·0	45	3·7	1·00
V.5.61.18 ...	5·7	43	3·3	·81
V.5.61.24 ...	5 6	46	3·2	·82
V.5.61.R. ...	6·0	45	3·2	·86
V.5.56.33 ...	6·0	46	3·3	·91
V.5 56.34 ...	6·3	47	3·3	·98
V.3.32.3 ...	5·5	50	3·2	·88
B.S.1.33 ...	5·8	36	3·2	·67
B.S.1.53 ...	6·1	35	3·2	·68
13.43.1,18 ...	4·8	47	3 2	·72
13.43.1.20 ...	5·1	45	3·2	·73
Ordinary Sea Island ...	5·8	44	3·1	·79

It may be noted that in the above table the best strain in regard to weight of lint per boll is V.1.9.19, which has a value in grams of 1·06, or 31 per cent. above ordinary Sea Island. A combination of the highest mean values recorded would give a weight of lint per boll of 1·176 gms.

Summary.

1. It is pointed out in this paper that the yield of Sea Island cotton depends on a large number of factors both morphological and physiological. Any scheme of selection must aim at a type the hereditary endowment of which will interact to the best advantage with environmental conditions.

2. The morphological characters of Sea Island cotton which are concerned with yield are discussed. It is shown that in respect of every one of these characters, a marked improvement can be effected by self-fertilization and selection.

3. The relative importance of lint index and lint percentage, as factors in selection work, is dealt with in some detail.

4. By following the methods of selection outlined in this paper it has been possible to isolate a strain of Sea Island cotton with a weight of lint per boll 31 per cent. greater than that of the ordinary type grown in the island.

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THE INHERITANCE OF IMMUNITY TO LEAF-BLISTER MITE (*ERIOPHYES GOSSYPII*, BANKS) IN COTTON.

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INTRODUCTION.

In previous papers (1915, 1916) the present writer has discussed generally the question of the immunity of certain types of cotton to *Eriophyes gossypii*, and has also given an account of crosses involving immune and susceptible varieties.

A summary of the more important facts so far established may be set forth as follows :—

1. Some varieties of cotton, e.g. Sea Island and Upland, are very susceptible to attack by the mite, certain indigenous West Indian natives and also some cottons of Brazilian origin are, however, completely immune.

2. In crosses between immune and susceptible types, the F_1 is attacked in varying degree. The resistance of the F_1 varies according to the particular varieties used as parents. The F_1 of certain crosses (e.g. Sea Island by Seredo type 1) is practically immune. In other crosses the F_1 is as susceptible as the susceptible parent (Upland by St. Croix Native).

3. In the F_2 of a cross between the immune variety St. Croix Native and the susceptible Sea Island variety Chance, segregation occurs into immune and non-immune. Some of the non-immune types are as susceptible as Sea Island, but a series of intermediates occurs of varying resistance, and between these no clear line of demarcation can be drawn.

Of late, much attention has been given to the question of the resistance of plants to fungoid diseases, and Biffen (1907) in a series of classic experiments obtained results pointing to the conclusion that the inheritance of resistance to rust in wheat follows the simple Mendelian law, susceptibility being dominant. Nilssen-Ehle (1911) did not obtain such simple results. He recognized several grades of resistance, and showed that crosses between two sorts of intermediate resistance could produce F_3 cultures both more and less resistant than the parents Further, from a cross between two sorts of high resistance were produced a number of lines in F_3 which were more susceptible than either parent.

Experiments such as these indicate the desirability of investigations into the inheritance of immunity to animal parasites in plants. Little work however, has been done in this direction. It is well known that American species of Vitis are immune to attack by Phylloxera, whereas the European types are very susceptible. Pasmuson (1914) found that crosses between phylloxera-susceptible species yielded phylloxera-susceptible offspring Crosses between phylloxera resistant species gave both susceptible and resistant offspring, with the latter dominant. Immunity to phylloxera was also dominant, and susceptibility

recessive, in the progeny of crosses between susceptible and resistant varieties.

Gernnert (1917) has pointed out that teosinte (*Euclanea mexicana*) is immune to the attacks of root aphis. Maize (*Zea indentata*) is often badly infested. The F_1 of a cross between teosinte and maize was completely immune.

The degree of success obtainable in experiments concerning the inheritance of immunity to animal or vegetable parasites depends largely on the nature of the material chosen for investigation. It has been emphasized by Mrs. Howard (1913) that in inheritance, at studies where the parents differ only in the degree to which the character under investigation is developed, and where a continuous series of intermediate types appear in F_2, it is necessary to have an analyser, i.e. a particular form in which the attribute under study is absent. Observations can then be restricted to a detection of the presence of the character involved. By a judicious use of analysers, and a careful analysis of the progeny, it is generally possible to determine by observation alone the principles underlying the inheritance

The immunity of certain cottons to *Eriophyes gossypii* provides such an analyser, for obviously a division can be effected into immune and non-immune. Thus, the material used in the present series of experiments is very suitable as a basis for study.

The present paper contains an account of the results of the F_1, F_2, and F_3 of a cross between the immune type, St. Vincent Native, and the susceptible type, Southern Cross Upland.

The F_1.

Similar results were obtained to those of former crosses, the F_1 being susceptible though not so susceptible as the Upland parent.

The F_2.

Segregation occurred into immune and non-immune. Of 465 plants 100 were immune and 365 non-immune. Most of the non-immunes were more resistant to the mite than the Upland grandparent. The presence of a large number of gradations in resistance, however, rendered impossible any further subdivision.

The F_3.

Families were grown from forty-seven F_2 plants. The F_3 results are presented below :—

(a) F_2 immune plants breeding true to immunity in F_3.

Family.	Immune.	Non-immune.
1-2-6	35	0
1-2-57	42	0
1-2-110	17	0
1-3-32	37	0
1-1-73	9	0
1-1-80	25	0
1-2-41	10	0
1-3-59	11	0
1-3-60	14	0
Total	200	0

(b) Families from F_2 non-immunes showing segregation in F_3, into immune and non-immune.

Family.	Immune.	Non-immune.
1-1-1	34	7
1-1-2	10	27
1-1-11	57	1
1-1-15	36	6
1-1-30	24	3
1-1-43	31	10
1-1-46	21	1
1-1-48	21	5
1-1-60	29	3
1-1-54	14	8
1-1-61	31	1
1-1-62	9	2
1-1-64	17	4
1-1-66	28	8
1-1-78	18	6
1-1-88	13	4
1-2-1	16	2
1-2-12	44	1
1-2-19	3	1
1-2-26	22	6
1-2-29	35	6
1-2-38	27	1
1-2-40	15	12
1-2-42	24	2
1-2-58	22	2
1-2-70	30	3
1-2-76	9	1
1-3-2	28	9
1-3-3	24	3
1-3-16	10	20
1-3-46	17	8
1-3-49	20	2
1-3-62	16	6
1-3-69	17	5
1-3-73	24	5
Total	796	191

It must be noted that the F_2 and F_3 cultures were allowed the fullest opportunity of becoming infected with the mite. The plants of the F_3 cultures were examined frequently, and as soon as a single typical gall appeared, a piece of red cloth was affixed to the plant; the reason for this was that plants have been known to throw off infection when attacked. Many plants recorded as non-immune remain relatively immune throughout the period of study. It may be remarked that neighbouring plots of Sea Island had no unattacked plants at the time when the F_3 records were taken.

Attention may be drawn to the chief points brought out by the table.

1. The ten families from F_2 immune parents bred true to immunity in F_3.

2. Of the thirty-seven families from F_2 non immune parents none bred true to non-immunity, but all threw immunes in widely varying ratios. Thus, in family 1-1-11, one plant only out of fifty-eight was attacked. The parent of this family was almost immune. In two families only was the proportion of non-immune greater than immune, viz., family 1-1-2 (10 Im.: 27 N-Im,), and family 1-3-16 (10 Im.: 20 N-Im.) Since full opportunity was allowed for infection in F_3, the absence of families breeding true to non-immunity probably implies that no families were produced in F_3 of the same gentetic constitution as the non-immune Upland parent.

3. The ratio of 100 immune to 365 non-immune obtained in F_2, and the ratio of ten homozygous to thirty-seven heterozygous families shown by the F_3 cultures, favour the hypothesis that immunity to the mite behaves as a simple Mendelian recessive. It may perhaps be argued, that if the cultures were left for a longer period, some would be found to be homozygous for non-immunity. That a few of the plants classed as immune would prove eventually to be non-immune cannot be doubted, but it is the opinion of the present writer that immunity to the mite is not yet shown to be inherited as a simple Mendelian factor. The somewhat meagre evidence renders it inadvisable to put forward any further hypothesis to explain the experimental results.

The fact that strains of cotton immune to the attacks of the mite can be obtained in the F_3 of crosses between immune and susceptible, is of great scientific interest, and is of no less importance from the economic point of view, for it opens up the way to the production of immune strains of Sea Island cotton.

Nature of the Immunity.

A few words may be said at this point on the cause of the immunity to the mite. The formation of galls in plants induced by both vegetable and animal parasites has been the subject of many theories. It would be of no advantage to recapitulate all of them. Beyerinck (1888) put forward a general hypothesis which is somewhat illuminating. He assumed that insects excrete a gall-forming material that has the character of an enzyme. This 'growth enzyme' influences the protoplasm of the host plant in such a way that the formation of a gall ensues. In the case under discussion, if the growth enzyme excreted by the mite has no effect on the protoplasm of the host, no galls can be formed, and the mites are unable to live on the plant. As a matter of fact certain structures may appear on the leaves of immune types which may possibly be incipient galls. This would seem to indicate that immunity lies in a lack of response by the plant to the particular stimulus exerted by the mite. Having shown that immunity is genetic, the question passes very largely out of the province of the botanist and enters into that of the bio-chemist. It is clear from what has been said, that the material used in this investigation offers attractive possibilities for research into the whole question of gall formation and its induction.

Summary.

1. The results of three generations of a cross between two types, immune and susceptible, respectively, to the mite *Eriophyes gossypii*, Banks.

2. The F_1 was intermediate, though inclining towards the susceptible parent. In F_2, segregation occurred into immune and non-immune. In F_3, immune bred true, while non-immune segregated into immune and non-immune.

3. The scientific interest and economic importance of the extracted immunes is briefly referred to, and the nature of the immunity is shortly discussed.

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CONCERNING COTTON IN ST. VINCENT AND THE STEPS WHICH MUST BE TAKEN TO SAFEGUARD THE INDUSTRY.

AN ADDRESS TO THE ST. VINCENT AGRICULTURAL AND COMMERCIAL SOCIETY, OCTOBER 19, 1918.

BY SIR FRANCIS WATTS, K.C.M.G., D.Sc., F.I.C., F.C.S.,
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The agriculture of St. Vincent has long been a matter of serious concern to those having responsibilites connected with it, and they have felt that the prosperity of the colony has been precarious. Subsequent to the failure of the sugar industry, the island depended very largely upon arrowroot, of which it produces a very fine quality in considerable quantity, but the demand for this is somewhat uncertain, and it is felt that this arrowroot industry alone is insufficient to maintain the financial safety of the colony. Other existing industries were relatively small and unable to sustain the colony. When in 1903 the cultivation of Sea Island cotton was introduced, it was hoped that the required new industry had been found which would ensure the colony's prosperity. How striking was the effect of this introduction of cotton cultivation may be judged from the remarks of Mr. W. N. Sands, the Agricultural Superintendent of the colony, at the West Indian Agricultural Conference in 1908. Mr. Sands said: 'A few of the indications of this satisfactory state of affairs, brought about in no small measure by the establishment of the Sea Island cotton industry, are the following: the revenue of the colony is exceeding the expenditure; exports and imports are rapidly increasing; estates are in full cultivation, and there is full employment for the peasant and labouring classes' (*West Indian Bulletin*, Vol. IX., p. 209.) This improved condition of things continued for some time, and the colony was lifted from the depressed condition into which it had fallen, and began to wear an air of prosperity, and it recognized that this prosperity was due to Sea Island cotton.

About the year 1911, however, doubts began to be entertained as to the stability of this prosperity, for while in that year the acreage planted in Sea Island cotton was very considerably increased, being returned as 5,068 acres, the yield of cotton per acre fell off in a somewhat alarming manner.

AVERAGE LINT YIELDS PER ACRE IN ST. VINCENT.

Crop year.	Pounds per acre.	Crop year.	Pounds per acre.
1905-6	174	1911-12	96
1906-7	175	1912-13	98
1907-8	135	1913-14	106
1908-9	124	1914-15	73
1909-10	141	1915-16	68
1910-11	159		
		Mean of averages	122

—*West Indian Bulletin*, Vol. XV, p. 257.*

* Subsequent information gives the yield per acre for 1916 as 66 lb. per acre, and for 1917-18, as 95 lb. per acre. The average yield of lint per acre for thirteen years is shown to be 116·9 lb.

Seeing that the rainfall of St. Vincent is far heavier than that of other neighbouring colonies growing Sea Island cotton, it was at first thought that the defective crops were mainly caused by the direct action of too heavy rain; soon, however, the observations of departmental officers made it plain that various pests and diseases were more responsible than rain for the falling off in yield: consequently through the succeeding years much attention has been paid to the incidence of pests and diseases in St. Vincent, the work there being further advanced and facilitated by the numerous observations on similiar lines which have been continuously carried on in other islands. As the outcome of all this, it was recognized that leaf-blister mite (*Eriophyes gossypii*), one of the pests earliest recognized as affecting cotton, was one which could be readily controlled by insisting on the destruction of old cotton plants at the end of each season, and legislation was accordingly invoked making this compulsory. But other troubles remained to claim attention. After much patient work on the part of several observers, it is now recognized that one of the principal diseases causing the loss of cotton in St. Vincent is that now known as internal boll rot. Investigations have shown that this is caused by certain specific fungi, of which four species have been found, and by some forms of bacteria, and that these are conveyed to the cotton plant by the action of various plant-sucking insects, notably by the cotton stainer, but also by the so-called 'bush-bugs' (*Nezara viridula*), and possibly by others.

The internal boll rot owes its great importance in St. Vincent to the fact that it is largely independent of weather, and cumulative, that is to say, the early instances of the disease provide infective material which is rapidly spread to later bolls by the agency of the plant-sucking bugs. This disease affects the cotton yield of the drier period, usually occurring from about the middle of November to February or March when the other diseases to be mentioned later, have gone off; in many cases it has completely destroyed the yield during this, the most dependable period in St. Vincent. Certain other plant bugs have been found to attack cotton; these include the leaf-footed tomato bug and the Pea Chink, and it has further been found that the large amount of shedding hitherto attributed to physiological causes is due to the presence of plant bugs.

In the process of obtaining this important information careful regard was paid to the methods which might be of service in controlling these troubles.

In the case of the cotton stainer, it was found that this insect has no parasitic enemies, and is preyed on by birds and lizards to only a neglible extent; trapping and hand collecting were therefore the remedies which first had attention, but these were troublesome and not thoroughly efficient. Further careful observations led to the conclusion that the food-plants of this insect other than cotton, were comparatively few in number, and consisted mainly of the fruits of the tree known as 'John Bull' or seaside mahoe (*Thespesia populnea*), and the silk-cotton, (*Eriodendron anfractuosum*). Other plants afford small quantities of sweet secretions on which the cotton stainers appear to be able to sustain existence for a time, but on which they do not appear to breed. In consequence of the information thus gained,

legislative steps were taken to give power to the Government to destroy the food-plants of the cotton stainer, and a vigorous campaign was undertaken by the Agricultural Department in the destruction of the two trees above mentioned; this was remarkably effective, and it is believed that if this is actively continued in conjunction with a close season for cotton, during which no cotton plant is permitted to exist in the colony, the cotton stainer may be eradicated. It is to be noted that the legislation under which this action is taken leaves it open for the Government to destroy any food-plant of the cotton stainer, consequently, should further research reveal the presence of other plants likely to prove dangerous in this relation, their destruction may be undertaken as occasion demands. In this connexion it should be stated that, observations having shown that cotton stainers may survive from season to season and breed on small heaps of cotton seed such as may occur in neglected corners of cotton ginneries, cotton stores, and similar places, legislative powers have been taken, making it obligatory for the owners of such places to keep them free from the neglected heaps of cotton seed, and the cotton stainers which may be encouraged by them.

The 'bush bugs' above referred to as being capable of conveying to cotton the infection of internal boll rot, appear to be less injurious than the cotton stainer, they do not appear to exist in such large numbers, and they are kept in check by certain parasites, principally by certain minute flies which lay their eggs in the eggs of the 'bush bugs', which then serve to nourish the young of the invading fly, thus destroying the eggs of the 'bush bug.' In addition to the destruction of the eggs of these insects in this manner, the insects themselves can be caught and killed, this being the more easily accomplished, from the fact that these insects usually make their appearance at definite times, and are not present in large numbers throughout the season. Furthermore, they are attracted to other plants more than to cotton, and, at least in certain observed cases, they do not appear seriously to attack cotton so long as other more appreciated plants are available to them.

Further investigations are necessary in connexion with these 'bush bugs' and other insects causing indirect attacks of disease on cotton, and it is hoped that, as these investigations proceed, means for combating the attacks will be found.

As an additional and necessary measure of precaution, steps have been taken to control by legislation and inspection the times of the sowing of cotton seed, and the destruction of the old cotton bushes at the end of each season, in such a manner as to ensure that there is a distinct period in each year during which no cotton plants are in existence, thus depriving both insect and fungus enemies of the means of carrying over from one season to another. The safety of St. Vincent largely depends on the rigid and thorough carrying out of the provisions of this legislation. Neglect to do this will lead to a recrudescence of the pests and diseases which can be controlled by these precautions, with the consequent loss of crops, and will cause uncertainty as to the efficiency of the measures recommended, together with trouble and expense in efforts to recover lost ground.

Other cotton diseases, in themselves serious, but owing to their dependence on wet weather, not so generally destructive as internal boll rot must be referred to. These, so far as has been ascertained, are a phytophthora soft rot of the bolls, which is responsible for heavy losses in very wet weather, and bacterial boll disease, which may cause heavy loss and staining of lint in ordinary wet weather, but the loss is not so complete as in the case of the phytophthora soft rot.

It will thus be seen that, instead of the simple explanation first put forward, the loss of much of St. Vincent cotton crop is due to too heavy rainfall, though that may account for some loss, a large proportion of the loss is traceable to fungus diseases of the boll, these diseases being conveyed to the cotton by the agencies of various plant-sucking insects whose habits are now becoming known, and therefore measures are being taken for frustrating their activities. It will be recognized that the whole matter is a very complicated one, and one which necessitates the concerted action of the whole community to deal with effectively; and it is recognized that the cultivation of Sea Island cotton involves concerted community action. Isolated individuals, however active and intelligent, are not likely to achieve success. This is a lesson which will have to be thoroughly learned and applied in St. Vincent, if the production of Sea Island cotton is to continue to maintain the prosperity of the colony, as it may well do.

It is the purpose of these remarks to call attention to other dangers which threaten the industry, and which must be guarded against, if prosperity is to be assured.

With relief afforded to his necessities by the cotton crop, the agriculturist in St. Vincent, in two many instances has treated his land much in the manner in which the holder of a short lease is tempted to do; he is taking all he can out of the land, and neglecting the measures which will maintain its fertility; he appears to be distrustful of the permanency of the cotton industry, and fearful of spending money in order to ensure that permanence, preferring rather to snatch an immediate profit, and to leave the future to care for itself. Such a policy is dangerous to the community, and especially dangerous from the administrative or Government point of view; for no matter who owns the land, the Government's functions and responsibilities still continue.

The observations of the agricultural officers, carried on over a long series of years, lead them to lay great stress upon the necessity for greater care in the matter of soil management, involving the more extensive and intelligent use of manure, including the use of pen manure and other locally prepared manures, of cotton-seed meal, of imported fertilizers and of green dressings, and also including such questions as the rotation of crops and other means of soil restoration.

The recognition of this need for care in manuring in relation to cotton was one of the determining features in the introduction by the Government of the oil-pressing machinery, the object being to prevent the export of the cotton seed, and to retain the residual pressed cake in the colony for use as cattle food and

fertilizer, thus preventing, to some extent, the depletion of the fertility of the soil.

In the Report on the Agricultural Department of St. Vincent for 1916-17, after discussing the result of the manurial experiments with cotton, the remark occurs 'The results presented are a very strong argument for maintaining the fertility of the soil by means of as heavy applications of manure as possible, and by a rational system of crop rotation.' Again, in a recently published report on the manurial experiments with cotton, Mr. S. C. Harland writes, 'In the light of the results of these manurial experiments it is expedient to warn planters that the characteristic signs of potash deficiency are very apparent on many estates in the island and it may be predicted with certainty that if there is a continuation of the present system of cultivation which insists on the burning of old cotton plants at the end of the season, and at the same time often makes no provision for restoring the fertility of the soil, the land will in many cases become so poor that cotton growing will become unremunerative. The effects of poor nutrition are made manifest not only by the presence of 'rust', but also by the stunted appearance of the plants, which succumb very easily to 'black arm', and are rapidly killed if attacked by black scale (*Saissetia nigra*, Nietn.). It is not apparent that defective nutrition causes these plants to be more susceptible to these affections, Healthy, well nourished plants seem to be attacked in just the same degree, but recover more quickly from the above mentioned diseases, while, if attacked by black scale, the plants do not suffer to the same extent as those badly nourished.'

With these facts before them, the cotton growers of St. Vincent will be well advised to look carefully into the situation, and to enquire what steps should be taken to preserve the fertility of their cotton fields. The first requirements appear to be the application of the ordinary principles of good agriculture, including the preparation and use of as much pen manure as circumstances permit. In this it is not sufficient to use only such quantities of pen manure as are now produced under existing conditions, but there must be exertion to produce more and more manure of this description, and to produce it scientifically and carefully, at the same time conserving it in such a manner that it does not suffer loss. These considerations will involve the taking of care in regard to the feeding and housing, or penning of stock, and to the use of covered pens, and other devices, matters which will be in the nature of an agricultural revolution in the colony.

In addition to this there should be consideration of the proper use of the large quantities of cotton-seed meal produced in the colony, so as to realize its full value for stock feeding, and incidentally as well as directly for manurial purposes. The question of the importation of manures and fertilizers, particularly of such things as sheep manure, will also need attention, and, in a general way, greater activity and enlarged expenditure in this direction will be called for.

In any scheme of soil improvement the use of leguminous crops can hardly be dispensed with, but there are considerations in the case of St. Vincent which make it necessary to proceed

with caution, and to be provided with very complete knowledge of certain circumstances connected with them, or trouble in respect to the cotton crop may ensue.

As the result of recent observations it is now known that many leguminous crops are food-plants of various plant-sucking bugs, some of which are able to convey to cotton the infection of internal boll disease; the bug most particularly noticeable in this connexion is Nezara; at the same time the important observations has been made, that these bugs appear to be more fond of the leguminous plants than they are of the cotton, so that if there is an abundance of the leguminous crop the bugs do not leave it to attack the cotton. Should, however, the leguminous crop be suddenly destroyed, so that the bugs are left without this source of food, then they may invade the cotton in large numbers; this is serious, for it also has been found that the seed pods of many of these leguminous plants may contain the fungus forms which give rise to internal boll disease, so that the bugs may be infected when they migrate, and may set up a disastrous epidemic of disease. From this it follows that if these leguminous crops are to be grown, they must be so timed that they may not have to be destroyed at a period when there is cotton to be infected; it may not be difficult to arrange this.

There is one other feature connected with these bugs; they are much attacked by insect parasites, and are thus kept in check. It will be remembered that no parasites of the cotton stainer have been found. These parasites attack the eggs of the bugs, laying their eggs in them, and thus preventing the hatching out of the bugs, a fresh brood of parasites appearing instead, so that the destruction of the bugs is progressive.

It should be quite possible, by examination of the fields of leguminous crops and of the favourite breeding plant 'Dove bush' (*Cleome viscosa*), to see whether they are badly infected with the bugs in question, and at the same time to see whether their eggs are parasitized; if they are abundantly parasitized, it is evident that the attack of bugs will diminish in severity, and much harm need not be anticipated. If they are not heavily parasitized, then it should be possible to introduce parasitized eggs from another district, and artificially to create the desired degree of parasitism to ensure the necessary degree of safety. It may well be that the Agricultural Department may be required to organize a service in this connexion.

With this knowledge carefully put into application in the manner suggested, it should be possible to employ legumnious crops in the scheme of soil improvement.

The use of leguminous crops for this purpose divides itself into two categories, namely, those which are used for purposes of green dressing the soil without producing any money crop, and those which are grown for the purpose of providing a crop to be sold.

The use of green dressing crops in St. Vincent is much to be recommended as a means of building up the soil which has been depleted by continuous cotton growing, and, fortunately, so far as is known, most of the crops which are suitable in this con-

nexion are not particularly dangerous to cotton because of their harbouring plant-sucking bugs.

Planters are, on the whole, well informed as to the plants which are available for this purpose of green dressing, so that it is not necessary to discuss them at length ; it will suffice to refer to Bengal beans and the allied velvet bean, and other Stizolobiums ; these grow well in St. Vincent, and a green dressing crop may often be interposed between two crops of cotton, thus causing no loss of time in regard to the use of the land for cotton growing. This use of the green dressing may fit in with the close season for cotton required by law. In this conexion I may add that it is now known that the beans of the Bengal and velvet bean class are not poisonous, but are suitable for stock food when properly employed : they are extremely concentrated foods, and the ill-effects which have been sometimes observed to follow their use are now known to be due to indigestion following the use of the beans in too great quantity, or when not mixed with a sufficient amount of other food.

Other green dressing crops may have consideration, including woolly pyrol and some of the Canavalias, to which frequent reference has been made in the *Agricultural News.*

Pigeon peas constitute a crop of value for green dressing : this crop, being largely grown in St. Vincent, requires no detailed reference. In order to obtain an adequate dressing, the crop must occupy the ground for some months, but this is offset by the fact that it can be grown for the purpose of obtaining peas for sale, as well as providing much material to be buried as green dressing ; thus the pigeon pea falls within the two categories mentioned.

As regards the leguminous crops to be grown for the sake of the crop of peas which may be sold, reference may be made to black-eye peas, and to ground nuts ; these may be grown as money crops where it is desired to rest the land from cotton, and at the same time to secure some monetary return. When a heavy crop of peas is taken off the land it is improbable that there will be much gain in respect to nitrogen ; that which may be gained from the air by the crop will probably not exceed that which is carried away in the peas removed, but still it is probable that the land will be left in an improved condition as the result of the change of crop.

Various other rotation crops may be considered, amongst them such crops as sweet potatoes, yams, cassava, eddoes, and corn, provided that their cultivation is carried on on intelligent lines, with proper regard for manuring and soil conservation.

Corn growing is likely to have more attention in the future in St. Vincent as the outcome of the influence of the Government Granary, by means of which the grain can be dried, so that it may be stored, and by means of which a ready market for the grain may be found. Corn can hardly be regarded as a restorative crop, but it may fill a useful gap in the colony's agriculture, and provide a money crop while resting the land from cotton. Its use will have to be carefullyconsidered, and care taken that it

does not result in the depletion of already impoverished land. It may be usefully employed as a short period crop, where it is desired to fill in an interval in connexion with the use of green dressing.

If an outlet can be found for sugar products, then sugar cane undoubtedly constitutes one of the best rotation crops with cotton. It has the advantage that it is a crop which tends to build up the humus content of the soil, and it is a cleaning crop, that is one which leaves the land relatively free from weeds when the crop is reaped: sugar-cane might be grown to advantage for, say, two years, to be followed by two or three years of cotton. The excellence of this rotation is well seen in St. Kitts where excellent crops of sugar and of cotton are obtained successively from the same land.

In considering the question of an outlet for sugar products, it would seem that the time may be opportune for giving attention to more extended manufacture of syrup in St. Vincent. It is doubtful if conditions are favourable, or if means can be found, for putting up in St. Vincent the elaborate and costly machinery required for the manufacture of sugar on modern lines, but simpler machinery will serve for the manufacture of syrup.

At the present moment sugar products are bringing high prices, and it may be possible to manufacture syrup profitably in such small and simple sugar works as can be constructed from the machinery still existing in the colony, eked out by the purchase of some of the machinery which is being discarded in neighbouring colonies, owing to the erection there of central sugar factories. The manufacture of syrup is attracting less and less attention in those colonies, as the central factory movement extends, while a good demand for syrup appears to be maintained in certain quarters. It is quite possible that some of the dealers who obtain supplies from Barbados will be glad to avail themselves of supplies from St. Vincent.

This line of enquiry appears to be one which it is desirable to investigate more fully, and also for enquiry to be made concerning the areas in the cotton districts which are capable of growing sugar, and the syrup manufacturing facilities which exist, or which may be provided.

In making these enquiries it should be borne in mind that the main object sought is the maintenance of the fertility of the land in respect to cotton, and that the cotton crop rather than the sugar crop, is the principal object of solicitude. The force of this will be seen when, as will probably be the case, the cotton growers express themselves content with the profits derived from cotton, and are disinclined to embark on the cultivation of sugar-canes.

In relation to all these matters emphasis may be laid upon he fact that the Agricultural Superintendent, Mr. W. N. Sands, is familiar with local conditions, and well versed in agricultural practice; his advice should be freely sought by those cotton growers who really desire to build up the fertility of their land, and add to the stability of the agriculture of the colony.

In matters relating to the immediate production of cotton, such as the maintenance of the required excellence of staple through seed selection and plant breeding, and the control of pests and diseases, it is essential that there should be common action on the part of all the cotton growers of the colony. In these matters individual activity must be co-ordinated to recognized ends, and must be prevented from militating against, and running counter to, certain accepted principles. For this reason it is wise and convenient to have Government intervention in many matters for the protection of the industry, and in the case of St. Vincent, for the protection of the colony, for the cotton industry is one which now is vital to the colony's existence. It is on these grounds that there is legislation relating to pest and diseases, to close seasons in regard to planting, to restrictions on the importation of seed. In this connexion it is to the interest of the community that the Government should be directly interested in the ginning and handling of cotton, so as to make more efficient this community action, which the peculiar circumstances of the Sea Island cotton industry render imperative. It is essential that the growers of Sea Island cotton in any given locality should work together to common ends; misguided action on the part of any individual may nullify the efforts of the whole body of cultivators. It is probable that the lack of recognition of this fundamental fact has led to the failure which has attended various attempts to introduce the cultivation of Sea Island cotton into many districts which appear promising. The significance of all this should not be lost upon the Government of the colony, nor upon the cotton growers themselves. It is not too much to say that were the general guidance of the Agricultural Departments to be removed, the Sea Island cotton industry would soon fall into difficulties. In a word, community action is essential to Sea Island cotton growing, and this action is best secured through the direct intervention of the Government.

The position is different in respect to the second matter having consideration in these remarks, namely the maintenance of the fertility of the cotton fields. Here everything depends on individual action, though the advice of the Agricultural Department is always available to assist and guide that action. It does not appear that there is here ground for active Government intervention, the actions of the individual reflect upon himself, and scarcely affect his neighbour; one man may build up his fields into a condition of marked fertility, while his neighbour may concurrently so deplete his as to make cotton growing unprofitable; neither, however, affects the other. The wise and able men, in this matter, are not detrimentally affected by their less wise neighbours.

References.

The following list of publications relating to work done locally in relation to the diseases of cotton bolls and of the insects concerned in their dissemination may be of service in connexion with the remarks in the foregoing paper.

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Sands, W. N. Notes on Trapping the Cotton Stainer in St. Vincent. *West Indian Bulletin*, XVII, pp. 47-9.

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Idem, 1914-15, p. 20. *Idem*, 1915-16, p. 23. *Idem*, 1916-17, p. 32.

A SUPPOSED NEMATODE DISEASE OF BANANAS.

BY WM. NOWELL, D.I.C.,

Mycologist on the Staff of the Imperial Department of Agriculture.

In May 1918 the existence in Grenada of a serious affection of the banana known there as the bluggoe*, and used extensively as temporary shade for cacao, was recognized by the Superintendent of Agriculture, Mr. J. C. Moore. In his report to the Commissioner of Agriculture Mr. Moore supplied the following description of the field characters of the disease :—

CHARACTERS AND INCIDENCE.

It appears that the disease may develop in plants of all ages, though its presence is most evident to the casual observer in plants that are approaching or have actually reached a fruiting stage.

A common characteristic is the drying of the outer leaves and then of the partly developed bunch, the fruits of which often dry to a hard blackened condition when only 2 or 3 inches long.

Plants examined do not show signs of disease in the parts most distant from the bulb and roots, the general impression conveyed by a survey of the affected plants being that they are suffering from lack of water and nourishment.

In every instance, examination of the bulb and roots revealed a root system almost entirely dead, or partly dead, and dying. The dead roots were either entirely black, or black between the cortex and the central cylinder. The outer part of the bulb from which the roots arose presented the same black disorganized appearance, and this was repeated to a lesser degree on the bulbs and roots of young suckers arising from the diseased parent.

Several hundred clumps have already been seen with the symptoms of this disease. The following notes refer to the conditions under which it occurs in three distinct localities.

A. About 300 to 400 stools of bluggoes planted with material from various sources two years ago ; over 50 per cent. of plants affected ; a crop of cane recently reaped from the land ; young cacao plants set to each stool. Two types of soil, one black and heavy, one brown and loose ; disease occurs on both. Trouble observed ever since plants reached maturity.

B. A field of several acres of limes interplanted last year with bluggoes, now fruiting for the first time. A view of the whole field conveys the impression that all the outer leaves of the bluggoe plants have been scorched. The dying commences along the margins of the leaf-blades.

C. Isolated clumps among mature cacao affected. The external symptoms, and the condition of the roots and bulbs are the same in all three cases.

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*A cooking banana believed to be the same as the 'moko' of Trinidad and the 'macaboo' of St. Lucia. [ED. *W. I. B*]

Nature of the Disease.

Spirit-preserved material from the first two localities was forwarded by Mr. Moore for examination. Slices of the diseased bulb show peripheral blackening penetrating to a depth of about an inch in places, and blackened areas isolated in section but connecting with the exterior at a higher or lower point. The thick roots have short vertical cracks, connecting with extensive discoloured patches spreading upwards and downwards in the tissue of the cortex, reaching in many cases to the central vascular cylinder but not penetrating it. The discoloured tissue is in various stages of disorganization, but in much of it the cell walls were not visibly decayed.

The affection has the general appearance of a fungoid disease, but neither hyphæ nor bacteria were present to an extent or with a uniformity suggesting more than a saprophytic rôle. On the other hand, nematodes (eel-worms) were regularly present in all the material examined; their eggs were present in the least altered and deepest seated of the discoloured tissue, and in some cases the worms themselves were seen occupying the cells of undecayed tissue close to the central cylinder of the roots.

In October the writer had an opportunity, during a brief visit to Grenada, of examining the disease in the field in the locality (A) first mentioned above. Mr. Moore's account of the symptoms was confirmed.

The affected plants are strongly marked by the withering of the leaves from below upwards, and of the leaf tissue from the margin towards the midrib. This appearance is symptomatic of root trouble in general; it was noted during a journey from St. George's to Sauteurs as common among bluggoes in many places, but how generally nematodes are associated with its occurrence is not yet known.

The condition of bacterial infestation described by J. B. Rorer in the 'moko' disease of the same plant in Trinidad was not present in the cases of the Grenada disease examined.

There was apparent evidence of varietal resistance to the disease in the situation referred to, where the Chinese (dwarf) banana and the 'silk fig' also occurred and were much less severely affected. The former at least seemed to be resistant to a degree which might permit of its successful cultivation in infested soil.

Reference to literature shows that N. A. Cobb (*Journal of Agricultural Research*, Washington, Vol. IV, pp. 561-68) has described an eel-worm, (*Tylenchus similis,*) as the cause of a serious outbreak of a disease of bananas in Fiji, in 1890-91, and has found the same species attacking sugar-cane in Hawaii, S. F. Ashby (*Bulletin of the Department of Agriculture*, Jamaica, Vol. II, p. 316) described a type of so-called blackhead disease in Jamaica, which he attributes to an eel-worm (identified later by Dr. Cobb as *Tylenchus similis*). The description of the condition of the roots and bulbs agrees in general with that given above.

Control.

From the nature of the infestation—minute worms living and laying eggs deeply within the tissues, capable of living

in the surrounding soil, possibly, as is the case with related species, resisting drying for months or years, infesting suckers on diseased plants—it will be seen that control may present difficult problems.

The first essential must be complete avoidance of the use of suckers from affected clumps as planting material. Where land is badly infested some other crop should be substituted. Direct treatment appears quite impossible. Ashby (loc. cit.) remarks regarding the Jamaica disease: 'The worms are widely present in cultivated soils, and even the roots of vigorous plants may show slight signs of attack. Unfavourable weather and soil conditions by checking active root growth and forcing the plant to depend on the older roots bring eel-worm injury into prominence, and make later recovery more uncertain.' Observations will no doubt be made as to whether more intensive cultivation will enable plants to 'grow away' from the disease in Grenada.

In a recent communication (December 1918) Mr. Moore reports that the plants referred to under (B) have shown considerable measure of recovery during the more favourable conditions of the wet season, presumably because more rapid root development has kept pace with the progress of the infestation.

The worm was referred to Dr. N. A. Cobb for the favour of identification, and is described by him as a new species in the paper which follows.

A NEW NEMA, *TYLENCHUS MUSICOLA*, N. SP., SAID TO CAUSE A SERIOUS AFFECTION OF THE BLUGGOE BANANA IN GRENADA, BRITISH WEST INDIES.

BY N. A. COBB, B.S., PH.D.,

Agricultural Technologist, Department of Agriculture, United States of America.

The writer is in receipt, from Mr. Wm. Nowell, Mycologist of the Imperial Department of Agriculture for the West Indies, of specimens of what is reported as a serious affection of the banana in Grenada. The specimens were preserved in 70 per cent. alcohol, and consisted of the roots of banana plants infested by a parasitic nema. The specimens were in a fair state of preservation, though in some respects not wholly favourable for exhaustive examination.

A preliminary account of the disease has appeared in the *Agricultural News*, Barbados, No. 422, June 1918,* which should be consulted with reference to the field aspects of the disease and the damage done by it.

*Reproduced, with some additions, in the present issue. [Ed. *W.I.B.*].

The following is a description of the nema :—

The rather thin layers of the transparent, naked cuticle are traversed by about 450 similar transverse striae, 1·4 microns apart near the middle of the body, which are not further resolvable. Rather faint but broad wings, beginning near the head and ending near the terminus of the tail, interrupt the striae in the lateral regions. The lip-region is $3\frac{1}{2}$ microns high and is supported by a rather weak but strongly refractive frame-work of a six-fold character, as indicated in the illustrations. There are three flat, almost imperceptible confluent lips without papillae. Apparently the mouth region is not very flexible. In the preserved specimens the anterior portion of the spear is distinctly visible, but the bulbs and hilt are rather 'ghostly', though well-developed. These two features of the anatomy illustrate well the fact which I have recorded elsewhere, namely that the anterior and posterior portions of the spear are of different origin, the anterior being of the same origin as the cuticle, while the posterior portion is of endogenous origin.

The hind part of the neck is cylindroid; anteriorly it becomes convex-conoid, the convexity being more pronounced near the lip-region. No amphids or eye-spots have been seen. That portion of the œsophagus leading from the spear backward to the median bulb, as well as that portion immediately behind the median bulb, is only about one-fifth as wide as the middle part of the neck. The prolate median bulb is three-fifths as wide as the corresponding portion of the neck, and contains a simple ellipsoidal valve one-fourth as wide as the bulb itself. A short distance behind the median bulb the œsophagus widens into a clavate posterior swelling. Doubtless this swelling is composed mainly of three salivary glands, as is the case in many other Tylenchi, but the condition of the specimens examined does not justify a positive statement in this respect.

The walls of the intestine are thick, its lumen faint. Its cells contain strongly refractive, colourless, spherical granules of variable size, the largest of which are one-fifth as wide as the body. These granules do not give rise to a tessellated appearance.

The conoid or slightly convex-conoid tail of the female comprises about thirty annules. It tapers from the anus to the blunt, rounded, unarmed and somewhat asymmetrical terminus. The excretory pore is located just to the rear of the nerve ring, and its more or less tortuous duct easily can be traced inward for a short distance. From the rather large, elevated, and conspicuous vulva, the medium-sized vagina passes inward at right angles to the ventral surface halfway across the body. Its walls are cutinized and refractive. In the tapering ovary, the ova are arranged for the most part in single file; only toward the blind end are they arranged

irregularly. Only one egg has been seen in the uterus at a time. A single measurement gave rise to the figures 62×18 microns. The egg was elongated, three-fourths as wide as the body, thin-shelled and smooth, and would apparently be deposited before segmentation.

The two equal, subarcuate spicula taper toward their distal extremities, where they are rather blunt. The bursa practically envelops the tail, but does not extend beyond it. Near the middle of the tail on each side in the lateral region there is a single digitate rib passing about halfway to the margin of the bursa.

Habitat: Roots of the bluggoe banana, Grenada, West Indies, where it causes a destructive disease. The description and measurements are derived from specimens preserved in alcohol and afterward mounted in glycerine jelly and in balsam.

Related Species

1. *Tylenchus similis*, Cobb, known to occur in Jamaica, though closely resembling *musicola* in form and size, is readily distinguished from it by the fact that the head end of the adult male is distinctly deteriorated; the spear has become almost rudimentary, as have also the median œsophageal bulb and other parts of the œsophagus, including the salivary glands. The bursa of *similis* does not completely envelop the tail, and this latter is longer and more slender than in *musicola*.

2. *Tylenchus penetrans*, Cobb, a wider nema, is very closely related to *musicola*. Compared with the width of the head the spear of *penetrans* is considerably shorter. The tail ends of the males of the two species are very much alike, so that the resemblances between *penetrans* and *musicola* are much closer than in the case already cited. It is not impossible that *penetrans* and *musicola* are identical, but the evidence so far available is against this supposition.

3. Another closely related species is *Tylenchus pratensis*, de Man. Up to the present time I believe *pratensis* has not been observed as a parasite, all the reported findings being of specimens living free in soil. It is nevertheless not impossible that it is parasitic, and that the individuals hitherto discovered have been such as were outside their host plant. The male of *Tylenchus pratensis* has a bursa that envelops the tail and extends a considerable distance beyond it, differing in this respect from the male of *musicola*. According to the published illustrations, the œsophageal bulb of *pratensis* is more elongated and less distinctly set off from the tubular portion of the œsophagus than in *musicola*. The spear of *pratensis* appears to be less robust than that of *musicola*, and the tail of *pratensis* is shorter. Although no one of these morphological differences is very striking, yet taken altogether they make it advisable to class *musicola* as a separate species, especially if *pratensis* is not parasitic.

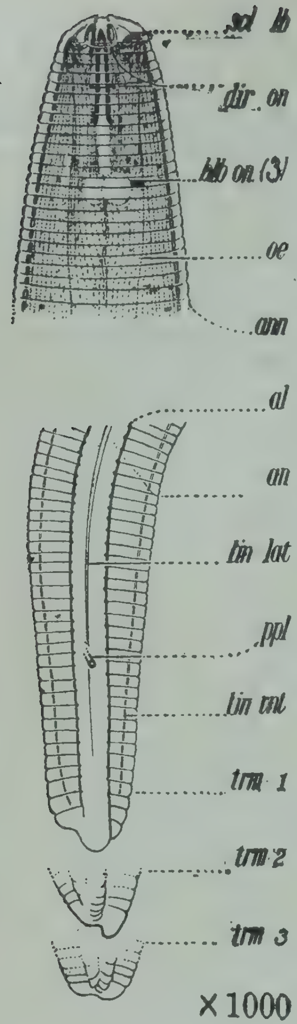

FIG. 1. Head and tail of the female of *Tylenchus musicola*, n. sp. Variations in the formation of the terminus are indicated at *trm* 1, 2 and 3. *Scl lb*, the framework of the lip-region ; *dir on*, guiding apparatus of the spear ; *blb on*, the three bulbs at the base of the spear ; *oe*, œsophagus ; *ann*, annule of the cuticle ; *al*, wing of the cuticle ; *an*, anus ; *lin lat*, right hand lateral line ; *ppl*, one of the two lateral papillae found near the middle of the tail of the female ; *lin vnt*, ventral line.

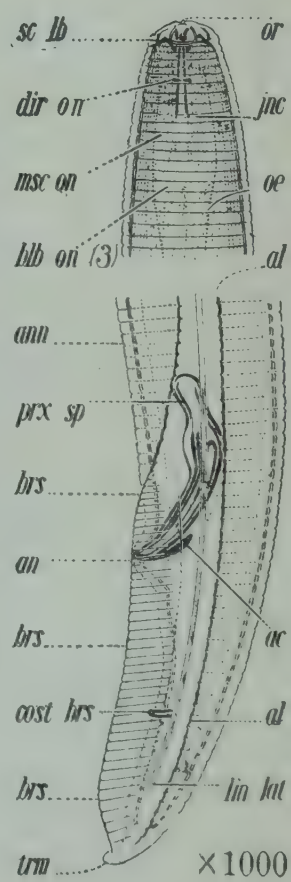

FIG. 2. Head and tail of the male of *Tylenchus musicola*, n. sp. These are shown in lateral view as in the case of Fig. 1. *Sc lb*, frame work of the lip-region ; *dir on*, guiding apparatus of the spear ; *msc on*, muscles of the spear ; *blb on*, bulbs of the spear ; *ann*, one of the annules of the cuticle ; *prx sp*, proximal ends of the spicula ; *brs*, bursa ; *an*, anus ; *cost brs* one of the ribs of the bursa of which there are only two ; *trm*, terminus of the tail ; *or*, mouth opening ; *jnc*, junction between the anterior and posterior portions of spear ; *oe*, œsophagus ; *al*, wing of the cuticle ; *ac*, accessory piece ; *lin lat*, lateral line.

ON THE SUCROSE CONTENT OF THE CANES CRUSHED AT THE ANTIGUA AND ST. KITTS CENTRAL SUGAR FACTORIES.

BY SIR FRANCIS WATTS, K.C.M.G., D.Sc., F.I.C.,
Imperial Commissioner of Agriculture for the West Indies.

In an article in the *West Indian Bulletin*, Vol. XVI, pp. 95-103, on the recovery of sugar at Gunthorpes Factory, Antigua, attention is drawn to the fact that the average sucrose content of the canes dealt with has steadily fallen off year by year, but no adequate explanation of the variation was, however, then forthcoming.

The sucrose content of the cane as shown by the yearly averages of all the cane dealt with in each season at Gunthorpes Factory, Antigua, and at Basseterre Factory, St. Kitts, has been as follows :—

Crop.	Antigua.	St. Kitts.
1905	15·3 per cent.	
1906	14·1 ,, ,,	
1907	14·4 ,, ,,	
1908	14·3 ,, ,,	
1909	14·2 ,, ,,	
1910	14·7 ,, ,,	
1911	14·1 ,, ,,	
1912	14·2 ,, ,,	14·6 per cent.
1913	12·9 ,, ,,	13·6 ,, ,,
1914	13·5 ,, ,,	13·5 ,, ,,
1915	12·0 ,, ,,	12·0 ,, ,,
1916	12·5 ,, ,,	12·8 ,, ,,
1917	13·0 ,, ,,	13·4 ,, ,,
1918	13·1 ,, ,,	13·0 ,, ,,

As regards Antigua, where the observations extend over fourteen years, the highest sucrose content was obtained during the first year under record ; this is succeeded by a period of seven years during which the sucrose content ranged somewhat over 14 per cent. ; after this came a period of six years during which the sucrose content fluctuates around 13 per cent., once reaching 13.5 and once falling to 12 per cent.

As is stated in the article in the *West Indian Bulletin* to which reference is made, 'it was thought that possibly, the falling off might be accounted for by the undue prolongation of the grinding season, but an examination of the records while showing that this has had some influence, leads to the conclusion that the circumstances are not thus fully accounted for, and there is a falling off of the sucrose content of the canes even in the better part of the seasons. It is possible that in dry seasons the sucrose content of the cane is increased even more than the fibre content, and that in seasons and places of heavy rainfall the canes contain smaller amounts of sucrose ; but even here we are faced with the fact that the years 1909, 1911, 1912, and 1913 were years of trying drought but of relatively low sucrose in the canes.

These remarks apply to Antigua; it is seen that there is a somewhat similar falling off in St. Kitts.

The year 1915 is somewhat remarkable, in that the sucrose content of the canes both at Antigua and St. Kitts fell to the remarkably low point of 12·0 per cent. It is curious that this should be the case in two separate islands. On referring to records from these islands it is found that the season 1914-15, when these canes were grown is stated to have been one of deficient and badly distributed rainfall. At Cassada Garden, Antigua, which may be taken as a typical situation in the area from which the factory canes were derived, the rainfall was 33·67 inches from April 1, 1914, to March 31, 1915; and it is stated in the Report on the Sugar-cane Experiments for that year that 'the rainfall was badly distributed; the dry weather experienced during August, September, and October exercised a very adverse influence on the growing crop which had been stimulated to growth by the favouring rains of the early portion of the year. In consequence the yields of cane were low and the quality of the juices in general, very indifferent.'

In the same report it is stated, as regards St. Kitts, that 'the rainfall was again deficient and badly distributed; as a result the crop produced was short.'

In these circumstances it may be concluded that the abnormally low sucrose content of the canes in 1915 may be accounted for by adverse seasons, but it would not seem that adverse seasons can be regarded as accounting for the progressive falling off of the sucrose content observed in other years.

It was thought that possibly the explanation lay in a steady deterioration of the canes grown in these islands; if this were substantiated, it would be a most disquieting fact, and one calling for active measures to arrest the decline. If there were a general deterioration in the quality of the cane produced it was argued that this should be shown equally in the canes grown under experimental cultivation on some seven or eight estates in Antigua, and some six in St. Kitts. It is to be observed that these experimental canes are grown on the ordinary fields of the estates, with the estate's cane crop, and subject to the same cultural conditions, and so should, and doubtless do, reflect fairly accurately the general trend of events in their respective districts as regards field crops.

The Annual Reports of the Sugar-cane Experiments in the Leeward Islands record the sucrose content of the juice from the canes grown on the experiment plots. Unfortunately the sucrose content of the actual canes is not recorded, but this has been calculated from the sucrose content of the juice, on the assumption that plant canes contain 15 per cent. of fibre, and ratoon canes 16 per cent. This may not be strictly correct, but it will be near the truth, and seeing that a difference of 1 per cent. affects the sucrose content to the extent of about 0·4 per cent., any error so introduced will not seriously affect the deductions which it is now sought to make.

The following tables contain the sucrose content of the canes of three principal varieties largely cultivated in these islands, namely, White Transparent, Sealy Seedling, and B 147

both as plants and ratoons, as calculated from the averages of the several plots annually reaped in each of the islands, and also of the canes dealt with at the two central factories. The three varieties selected comprise by far the greater part of the canes dealt with at these factories.

ANTIGUA.

Year of reaping.	White Transparent.		Sealy Seedling.		B. 147.		Factory.
	Plants.	Ratoons.	Plants.	Ratoons.	Plants.	Ratoons.	
1902 ...	14·3	14·2	14·1	...	14·0	13·8	...
1903 ...	16·0	15·6	14·6	15·7	15·1	15·2	...
1904 ...	15·2	15·9	14·3	15·1	14·1	15·1	...
1905 ...	15·9	15·6	14·9	15·1	15·1	14·9	15·3
1906 ...	15·5	15·4	15·0	14·2	14·9	14·1	14·1
1907 ...	14·8	15·6	15·0	14·8	15·2	14·0	14·4
1908 ...	16·4	16·6	15·0	15·2	15·0	15·1	14·3
1909 ...	15·6	14·9	14·6	14·3	14·1	15·0	14·2
1910 ...	16·1	15·3	15·4	14·9	16·0	14·7	14·7
1911 ...	15·6	15·6	13·7	14·3	14·7	14·8	14·1
1912 ...	16·0	16·0	14·5	14·7	14·8	14·0	14·2
1913 ...	15·9	15·6	15·4	14·2	15·0	14·3	12·9
1914 ...	16·3	15·8	15·2	14·7	15·5	15·2	13·5
1915 ...	14·7	12·8	14·1	12·8	14·3	13·2	12·0
1916 ...	15·6	14·9	14·4	14·2	14·5	14·3	12·5
1917 ...	16·6	15·7	15·4	15·5	16·0	14·4	13·0
1918 ...	15·7	15·1	15·4	14·8	15·1	15·1	13·1

ST. KITTS.

Year of reaping.	White Transparent.		Sealy Seedling.		B. 147.		Factory.
	Plants.	Ratoons.	Plants.	Ratoons.	Plants.	Ratoons.	
1902 ...	13·7	13·4	...	...	13·7	14·0	...
1903 ...	12·4	14·3	...	...	13·0	13 8	...
1904 ...	13·9	13·8	...	...	13·4	13·0	...
1905 ...	14.7	15·7	...	...	14·0	14·0	...
1806 ...	14·7	14·3	14·2	...	15·3	14·1	...
1907 ...	14 7	14·5	13·7	13·5	14·8	14·3	...
1908 ...	14·1	13·7	12·9	13·6	13·9	13·3	...
1909 ...	13·6	14 0	12·8	13·7	13·6	14·5	...
1910 ...	13·3	15·3	13·6	14·6	13·3	15·0	...
1911 ...	13·2	1·39	13·1	12·5	13·1	13·6	...
1912 ...	14·2	13·9	13·9	14·3	14 2	14·7	14·6
1913 ...	14·1	14·6	13 9	14·2	14·0	13·9	13 6
1914 ...	13·1	13·6	12·7	13·1	13·1	13 8	13·5
1915 ...	12·3	12·6	12·1	12·9	12 0	12·5	12·0
1916 ...	14·3	13·8	13·4	13·7	13·8	13·8	12·8
1917 ...	14·6	15·8	13·8	14·5	14·9	14·6	13·4
1918 ...	14·3	15·4	14·0	13·7	14·1	14·3	13·0

It will be observed that, while there is fluctuation in the case of the sucrose contents of these three canes, this fluctuation does not trend downwards, as is the case with the figures relating to the factory canes. It is somewhat curious that in every cane here recorded, that is to say, in all three varieties of canes and in the factory canes at Antigua as well as St. Kitts, a remarkably low sucrose content is common to all in the season 1915. This feature has already been discussed in connexion with the factory canes, and it is believed to be due to the peculiar climatic conditions of that season.

If the sucrose contents of the canes in 1915 are eliminated, it is seen that the figures relating to the sucrose contents of the other canes fluctuate around a mean, and that the sucrose contents of later years are as high as those of the earlier years, being thus in marked contrast to the sucrose contents of the factory canes whether at Antigua or St. Kitts, which have steadily deteriorated. It is reasonable to conclude, therefore, that there has been no specific deterioration in the quality of the canes ordinarily grown, that is to say, there has been no specific deterioration in the varieties cultivated, while there has been deterioration in the quality of the canes delivered to the factories.

It is suggested that this deterioration of the factory canes may be due to two or three causes. It is not improbable that the canes have not been cut in the manner that was customary when the crops were reaped for the purpose of making muscovado sugar; in that case care was taken to exclude the unripe, upper portions of the cane. Under factory conditions, where the principal consideration of the cutter and seller is that of weight, it is not unlikely that these unripe portions are not excluded; they weigh well, and therefore there may be a strong tendency to include them.

Again, in the effort to get as much cane as possible for the factories, it may be that fields of inferior, stunted canes have been reaped, thus lowering the average sucrose content.

It is also suggested that some deterioration may take place from canes being kept for some considerable time after cutting before they are crushed, a condition which has been accentuated by difficult labour conditions.

There may be other causes at work; but with this analysis of the situation, it would seem that these causes must be sought by the managers of the factories and by the planters themselves; the material passes through their hands, and they alone have the means of accumulating the data necessary for further discussion. The matter is hardly one concerning which official records or investigations are calculated to throw much further light unaided by those concerned with the factories and estates.

The first named cause of deterioration in quality, namely the cutting of the cane in a manner different from what was formerly the case, but which would persist in the cutting of the experimental canes, most probably accounts for the difference. If this is so, the sellers of cane have been able to increase the weight of the cane delivered, at the expense of the quality. This tendency to a modification of the manner of cutting the canes when transferring from a muscovado to a factory basis, is one which must be looked for and taken account of when such changes are contemplated, for it would seem that there is a possibility of a depreciation in quality setting in to an extent of 1 in about 14 of sucrose, that is about 7 per cent. of the total value of the cane. It may be a matter for argument whether it is economically sound to cut the canes with the less ripe portions attached so as to avoid wasting such sugar as it may contain; but it is quite clear that it alters the basis of valuation of canes so dealt with.

MR. G. MOODY STUART, the Managing Director of Gunthorpes Factory, Antigua, Basseterre Factory, St. Kitts, and Ste. Madeleine Factory, Trinidad, commenting on these notes, says :—

'I had been feeling anxious myself for some years, but I thought the cause was probably that we had got into a cycle of poor seasons and that we might hope to get out of it again. In my opinion one ought to eliminate the year 1915 entirely from any review of this matter, for as you would see from our Ste. Madeleine Annual Report of that season, the unusually low yield of sugar was a common feature throughout the West Indies in that year ; that the Cuban and Porto Rico factories had taken one or two tons more cane to make a ton of sugar than in any season since the introduction of modern machinery, and this was apparently due to the absence of cool nights, which are required during crop time for the ripening of the cane. But when 1915 has been eliminated, there still remains a great deal to be accounted for and cured.

'We have been watching the point of the better trimming of canes for several years, and in the last two years at least it is stated that the canes in Antigua have been delivered much freer from tops than before, and in the St. Kitts report for crop 1916, you will see that we remarked there "that the canes were better cleaned and trimmed than previously".'

A later communication from Mr. Stuart states that Mr. La Salle, the Chemist of Gunthorpes Factory, Antigua, feels fairly sure that the deterioration in the sucrose and purity of the canes as ground in that factory, which has been going on from year to year, arises mainly, and very likely entirely, from the staleness of the cane, except in two seasons when there was an unusual amount of stand-over cane, which would account for part of the deterioration.

(Pages 119 to 188, issued 7th April, 1919.)

THE RED RING OR 'ROOT' DISEASE OF COCO-NUT PALMS.

BY WILLIAM NOWELL, D.I.C.,

Mycologist on the Staff of the Imperial Department of Agriculture for the West Indies.

An affection previously known as the Trinidad root disease, but which it is now proposed to distinguish as red ring disease, is responsible for the loss of many coco nut palms in Trinidad, Tobago, and Grenada. In the great majority of cases the trees die soon after reaching maturity, during the bearing of the first few bunches of nuts, but instances have been verified of the death of trees not less than twenty years old.

Some confusion has existed between this disease and infectious bud-rot, owing to the fact that putrefaction of the soft tissues of the enclosed central shoot is exceedingly liable to accompany the death of the coco-nut palm, whether this arises from mechanical injury, from chemical poisoning, or, as in the disease in question, from the presence of parasites.

The attraction of the palm weevil (*Rhynchophorus palmarum*) to the fermenting tissues has sometimes given rise to the belief that this beetle was involved in the origination of the failure.

When trees which are obviously failing, but have not reached the final stages, (Pls. I and IV) are cut down and examined, there is, in most cases, no trace whatever of bud-rot or of weevil injury, while infestation with the parasite hereafter described is already general and severe.

From an early stage in its investigation the most definite distinguishing feature of the disease has been recognized to be the existence in the stem of a well-marked zone, usually 1-1½ inches wide and beginning 1-2 inches from the periphery, in which the ground tissue is dull red, or red mingled with yellow. This zone is best developed in the basal half of the stem. It is generally referred to as the red ring, from its appearance as such in a cross section of the stem. (Pl. III.)

HISTORY.

Mr. J. H. Hart, (1) Superintendent of the Royal Botanic Gardens, Trinidad, in 1905 had his attention called to a coco-nut disease prevalent at Cedros on the western coast of the island. He reported that a typical example showed infection from the ground upwards, and had a ring of red discolouration lying inside the woody exterior of the stem. His observations led to the conclusion that there had been a succession of losses of the same kind for many years.

As an outcome of Hart's report, Mr. F. A. Stockdale, (2, 3) Mycologist on the Staff of the Imperial Department of Agriculture, was assigned to the investigation of coco-nut diseases in Trinidad, and visited the island for that purpose from July 10 to August 14, 1906. In a lengthy report Stockdale distinguished between root disease and specific bud-rot, and recognized the tendency of the bud to putrefy in the case of trees dying from any cause. He described the symptoms of root disease with a fullness that leaves no room for doubt as to its identity with the present affection. He observed the fruiting of a *Botryodiplodia* to be general near the base of failing leaves, and assumed that fungus hyphae found in the affected roots pertained to the same species. He came to the conclusion that the fungus was the immediate cause of the disease, that this began with an infestation of the roots, that the red zone in the stem was an effect of the stoppage of the water-supply, and that a secondary infestation of the leaf bases followed.

In 1907 Mr. O. W. Barrett, (4) U. S. Department of Agriculture, reported that about 95 per cent. of coco-nut losses in Trinidad were due to root disease, and that only a few cases of bud-rot occurred.

Mr. J. R. Johnston, (5) Assistant Pathologist, U.S. Department of Agriculture, visited Trinidad during his investigation of the bud-rot disease, and recorded his conclusions in a short paper issued in 1910. After reviewing the work of previous investigators he dismissed Stockdale's root disease as non-existent, and stated his opinion that the only destructive disease of the coco-nut occurring in Trinidad was identical with bud-rot as generally understood. The putrefaction of the bud which Stockdale reported as accompanying the death of the tree from root disease was regarded by Johnston as evidence that the disease was bud-rot and nothing else. He denied that such putrefaction was a natural sequence of death from any other cause.

Mr. J. B. Rorer, (6) Mycologist to the Board of Agriculture, Trinidad published in 1911 his conclusions from studies of coco-nut diseases extending over a period of two years. He fully

confirmed Stockdale's conclusions as to the existence and severity of root disease as distinct from bud-rot, but pointed out that Stockdale's assumption that it was caused by *Botryodiplodia*, or by any fungus, was unsupported by evidence of even the slightest value. Rorer made an extensive mycological examination of material from diseased trees, and gives the following account of the results of 194 tube cultures :—

Cultures have also been made from all parts of the diseased trees both by the poured plate method and by cutting out small bits of the affected tissue under aseptic conditions and putting them on sterilized potato cylinders or agar in tubes. In all, 194 tube cultures have been made from diseased trees from Cedros, the East Coast, and Tobago, and the results have been uniformly the same. In cases in which cultures have been made from portions of the root which showed only slight discoloration, or in other words, the first signs of disease, no growth of any kind has taken place, except occasionally where contamination evidently took place from the air. This supports the results of the microscopical examination that there is no fungus in such roots. When the cultures were made from the more discoloured root tissues the results were very variable. About one-half the tubes remained sterile, showing that there was no fungus in the bit of tissue used, while the others gave a variety of things, generally mixed cultures of fungi and bacteria. No one fungus was found constantly in the cultures, and in no case, except where very rotten and black roots were used, was Diplodia obtained. The commonest fungus which was found was a species of Fusarium.

Rorer sums up as follows :—

Finally, the work of the past two years shows rather conclusively that it is not due to a Diplodia or to any fungus parasite, in fact all the observations point to the conclusion that it is a physiological trouble resulting from unfavourable conditions in the soil. Whether it is the lack of some element necessary to the continued growth of the coco-nut tree, whether it is the presence of some substance which is toxic to coco-nut roots, or whether it is due to acidity or lack of aeration in heavy soils it is difficult to say. It is very noticeable, however, that the disease is only found to any considerable extent in places where the trees are planted on land which is not good coco-nut soil, or in places where the trees have received no cultivation whatever. Another point worthy of note is that the disease is frequently met with on old sugar land.

The present writer (*) first saw the disease during a ten days visit to Grenada in 1918, made in consequence of a report from Mr. J. C. Moore, Superintendent of Agriculture, that losses were becoming increasingly frequent among the considerable number of coco-nut trees planted during the previous five to ten years. During a visit to Trinidad (⁹) made in connexion with sugar cane diseases, and extending from December to February 1919, occasional opportunities arose of making observations on the disease. In February of this year another week was spent in Grenada in its investigation.

Sufficient information has been obtained for a description of the disease as it appears when fully developed, and for the announcement of its invariable and close association, in all cases examined, with a nematode worm which the writer believes to be its cause. The mode of infection and the early course of the development of the disease remain for investigation, but, as the writer is going on leave for some months, he has considered it advisable to put forward an account of the results so far obtained.

Distribution and Incidence.

Reference has been made to Hart's conclusion that the disease had been present at Cedros for an indefinite but lengthy period previous to 1905. It is at the present time very widely distributed in Trinidad, and has caused heavy losses in Tobago. There is no record of its occurrence in Grenada previous to about 1916, when deaths now attributed to this cause began on the Westerhall plot. The rather general movement towards coco nut planting which was made a few years ago in Grenada has been ollowed by the occurrence of the disease in various quarters, fncluding the northern and southern extremities of the island.

i There is no record of the presence of the disease elsewhere than in the islands mentioned. It may very well occur in South America without having been reported, but does not appear to be present, so far as recent experience shows, in the islands of the Lesser Antilles north of Grenada.

Definite information regarding the number of trees destroyed by the disease is scanty. The extent of liability to loss at any one time depends in the first place on the number of trees passing through the critical period, which extends from the fourth to the seventh year. For this period the death-rate may extend to 30 per cent., which is the owner's estimate in respect of an extensive young plantation in one of the islands. In the government plot at Westerhall, Grenada, now six to seven years old, out of sixty trees, grown under favourable conditions, eighteen have been lost from 1916 onwards; at the present time, from outward appearance and from borings made in the stem of each tree, no further cases can be detected. This would give a loss during the critical age of 30 per cent. in this case also, the seriousness of which appears when it is remembered that it means the loss of about five years' cost of cultivation and the deferring of returns for at least a second five years, with prospects of repetition of the loss through reinfection of the plants used to supply vacancies.

After the critical age is passed losses from the disease very rapidly diminish, but cases occurring up to ten years are not particularly rare, and, as previously mentioned, odd cases have been verified in trees over twenty years old.

So far as the writer knows, the only occurrence of the affection in other palms which has to be recorded is one which was verified during his most recent visit to Grenada, when a specimen of an unlabelled species of Cocos in the Botanic Gardens, with a stem measuring 29 feet, died with all the usual symptoms of the disease, and with full nematode infestation of roots, red ring, and petioles.

External Symptoms.

Descriptions of the visible process of failure have been given by Stockdale and Rorer, and with these the observations of the writer agree. The salient features are as follows:—

(a) Progressive yellowing and browning of the leaves take place from below upwards, commencing at the tip of each leaf reached in the process. Commonly the lowest living leaves are

the first affected, but occasionally one or several of these may remain green while the discoloration, commencing above them, successively involves the younger leaves. In its early stages the process is indistinguishable by external appearances from the natural dying-off of the old leaves, especially where this is accelerated by drought, water-logging, or poor conditions of growth in general. The difference becomes apparent, however, from the steady march of the discoloration, which soon begins to involve leaves in full vigour, and continues to those in which the leaflets are not even fully expanded. The process is relatively rapid. The Grenada tree in Plate I, which when photographed on February 22 was exceedingly conspicuous from its rich colouring of brown, orange, and yellow, involving all but the central tuft of leaves, attracted no attention in early January when the plot was visited by the Superintendent of Agriculture for the purpose of detecting diseased trees.

(b) The shedding of green nuts of all sizes present takes place concurrently with or slightly in advance of the discoloration of the leaves, and is thus in some cases the first external sign of trouble. Associated with this symptom is the shedding of open and unopened flowers, and partial withering of the branches of the inflorescence, extending finally even to the contents of the still unopened spathes. In this connexion it must be remembered that shedding of small nuts often occurs in healthy trees.

As secondary symptoms there occur :—

(c) Development of patches of brown or black rot, wet but firm, on the expanded leaf bases, and sometimes of similar patches on the leaf-stalk higher up. This appears to be the chief reason for the tendency for one to several of the leaves of affected trees to break, often at one to 2 feet from their insertion, and hang down. The patches here referred to seem invariably to develop crowded pustules of *Diplodia* sp. (which may equally well be designated *Botryodiplodia*), presumably corresponding to Stockdale's fungus. A comparable infestation of the failing branches of many trees, notably of cacao and lime, with *Diplodia* spp. is frequent and well-known in these islands; the status of *Diplodia* being now generally admitted to be mainly that of a saprophyte, with powers of parasitism limited in most cases (the exceptions being usually fruits) to the invasion of tissues with less than normal vigour. Such infestations are common if not general in healthy coco-nut palms on leaves approaching senility. The extension of a similar failing condition to younger leaves in the trees affected with red ring disease seems quite adequate to account for the association of Diplodia rot with that affection. The existence of nematode infestation in these leaves long before the fungus reaches them will be described below.

(d) In cases allowed to reach the final stages there ensues a putrefaction of the soft tissues forming the apex of the stem and the base of the central column of unexpanded leaves, as also of the similar tissue at the base of the young inflorescence. In each case this involves tissue deeply enclosed by the sheathing bases of the leaves (Pl. IV). The experience of the writer supports Stockdale's opinion that putrefaction of the region of

the bud is a normal sequence of any injury sufficient to bring about the death of the tree. There is no sound basis for the assumption that any necessary connexion exists between this mode of decay and infectious bud-rot disease. (The occurrence of bacterial putrefaction and a bad smell applies equally to the heart of a rotting cabbage.) The writer has previously recorded (7) the case of a perfectly healthy coco-nut palm in Barbados (where no bud-rot occurs) poisoned by inserting sodium arsenite at the base of the stem, in which complete putrefaction of the bud occurred within two weeks. Recently the top of another healthy tree was cut off with an axe, with a similar result ensuing in six days.

Johnston's contention that bud-rot is the cause of death in the Trinidad disease could, one thinks, never be made or upheld after examination of any typical case such as those shown in Plates I and IV, in which trees known from experience to be near inevitable death show no trace whatever of bud-rot, and in which, in fact, the central tuft enclosing the bud is the only part of the foliage preserving a completely healthy appearance.

Internal Symptoms.

The description of the internal symptoms of affected trees which follows refers to the stage of development of the disease in trees which have reached the condition of those illustrated in Plate I, in which the tree still retains its normal shape, but only the central tuft of partly expanded leaves is still a healthy green, while the remaining leaves show various stages of ill-health from merely yellow tips to complete yellow and brown discoloration. The succeeding stages of failure are gone through rapidly, and are usually dominated by the secondary symptoms already described.

The Stem.—The usual distribution of the red zone in the stem at this time is seen in the vertical section of a standing tree shown in Pl. IV. The zone completely surrounds the base of the stem, extends upwards as a solid band of reddened tissue for about 4 feet, then breaks up into longitudinal streaks and finally into scattered dots about 1 millimetre in diameter. In the latter form it extends to the soft meristem underlying the bud, in which region the dots appear to be generally dispersed below the flattened apex of the stem.

All the cases seen by the writer have had the red ring in the situation described, but Stockdale records that when failure of the leaves has begun higher than usual, so as to leave a ring of the lowest leaves unaffected, the discoloration of the stem is found towards the centre. Rorer figures a similar instance, reproduced here in Pl. II, Fig. 2.

The Leaves.—When the leaves of a tree in the stage now under description are removed one by one and split open in the median line, a similar homogeneous red, red-spotted, or red and yellow-streaked and mottled discoloration is revealed in the leaf-stalk, extending in the fully developed leaves from the base to a distance of from 6 inches to 2½ feet outwards. In the older leaves it becomes wholly or partly masked by the development of brown rot, or by the natural browning of the tissues. Parts of four mature leaves

from the tree in Pl. I are shown in Pl. III, Fig. 1. The first piece from the left shows brown rot at its extremities, with red mottling between. The second is a healthy green leaf which was the only one below the point from which the leaves began to fail. The third shows deep red mottling with brown rot above, and the fourth, mottling without brown rot.

When the compact upright column formed by the leaves not yet bent outwards from their base is examined, the red discoloration of the petioles continues, often with great intensity, although the leaves themselves, as the centre is approached, are healthy in appearance, or but slightly tinted yellow at the tip. The first four leaves seen in section in Pl. IV., beginning on the right, were infested from the base, in order of age, for 12, 9, 6, and 6 inches, respectively. The fifth showed only scattered pink spots and lines, and the remaining young leaves were sound. In two other cases examined at the same time, the tree in Pl. I and another similar to it, bright red and yellow discoloration occurred, with decreasing extent and intensity, in the soft white tissue of each still younger leaf so far as these could be distinguished. (cf. Pl. VIII. Fig. 1).

It is a notable fact, and may prove to be significant, that, in the examples closely followed out, the area of discoloration tended in the younger leaves to recede from the base, retaining at first a narrow connexion on the dorsal side, then leaving it altogether. In the record made of a very young, still enclosed leaf, for example, the basal 9 inches was perfectly white soft tissue, then from the point of attachment of the first leaflets there was an enclosed central infestation shown by vivid red and yellow spots and extending for $2\frac{1}{2}$ feet.

The Roots.—The effect of the disease on the tissues of the roots is confined to the cortex, which consists of radial lamellæ loosely packed into the region between the horny hypoderm and the central woody strand. This tissue is pure white and soft when healthy, but when affected by the disease under consideration it becomes dry and flaky and passes through stages of discoloration from white to light yellow or pink, then to dark yellow or reddish brown. Affection of this nature in the root may extend for any distance from an inch or two to 10 or 12 feet from the point of attachment. In all cases examined by the writer it has been continuous, and decreasing in intensity outward from the base of the tree. In some cases all the roots examined have been discoloured for several feet; in others the range of variation given above has been found in the roots of one tree, while in the tree mentioned above as having its leaves infested to the centre, only two or three roots were found discoloured, and these only for an inch or two, although the tree was dug out and a thorough examination made.

The Association of Nematodes with the Disease.

Examination of stained sections of a large amount of material from all sources confirms Rorer's conclusion as to the absence of any causative relation between fungi and the disease. Hyphae have been found to be rarely present in the diseased living roots, and never until the degree of discoloration has

reached an advanced stage. They have not been found in the discoloured tissues of the stem nor in the very definite lesions existing, without visible connexion with the surface, in the petioles of the young leaves.

On the other hand, there is a perfectly constant association of nematode worms with the lesions existing in stem, leaves, and roots; an association which begins with the first trace of discoloration, and persists until the infested tissue is dead and decayed. The scattered red dots in otherwise sound living tissue, which mark the upward extension of the red zone in the stem and the beginning of infestation in the leaf-stalks, are initial nests containing usually a few adult worms together with immature specimens and eggs. The red zone in the stem is, in its every part, simply a vast infestation with myriads of active worms.

In sections of the tender white meristem of the upper extremity of the stem and of the embryonic leaves, the worms may be seen in large numbers, threaded along between the cells like fungus hyphae, or lying coiled up in one of the larger intercellular spaces. In these situations they are by no means confined to the discoloured spots, but appear to be able to travel in any direction through the living tissue.

In the roots the worms are present in large numbers, closely and invariably associated with the typical discoloration. It is remarkable that in no case have eggs or young worms been seen in the hundreds of examinations made of the root tissues. The great breeding ground is the red zone in the stem, and judging by the relative abundance of eggs, reproduction appears to be most active in its upper less-developed sections.

The infestation is in all cases confined to the ground tissue, the vascular bundles remaining to all appearance unaffected in any way.

The restriction of infestation in the stem to a narrow zone, and the definite location of this zone in each individual case cannot at present be satisfactorily explained. Attempts to connect it with the anatomy or functions of the stem have not succeeded. It is now conjectured to be the resultant of infestation near the growing point and the subsequent expansion of the stem.

In mature stems examined the following structure has been made out. There is first a fibrous zone some ½ inch thick corresponding in position with the bark of a dicotyledonous tree. The main body of the stem beneath this is divisible into three concentric regions marked by the opposed directions of the spiral course of the vascular bundles. There is (a) an outer zone, not usually more than an inch thick above the swollen base, in which these are thickly massed and nearly vertical, then (b) a middle zone up to 2 inches wide with a decided spiral ascending to the right or to the left, and then (c) a wide core, 5 inches and upwards in diameter, with more scattered bundles directed to the left or right respectively. Differences in diameter of the stem mainly affect the last mentioned region. In Pl. V the spots are in the outer zone, while the solid discoloration coincides with the first inch of the middle zone, but leaves the

remaining ¾-inch of the same quite unaffected. The main leaf traces pass across the infested zone without influence upon it.

In all the cases seen by the writer the ring has occupied about the position indicated above, but as already mentioned, both Stockdale and Rorer mention cases where the location has been more central.

The Evidence of Causation.—The theory that the nematode in question is the cause of the disease rests upon the observations detailed above, which amount to this: that the worms are closely and invariably associated from its initial stage with each of the primary symptoms developed, while the symptoms classed as secondary are common to coco-nut palms failing from any cause. It would in fact appear to be the most accurate expression of the case to say that infestation with nematodes constitutes the disease, its essential anatomical characters being to all appearance the direct result of the presence of the worms.

Attempts are being made to produce the affection artificially by introducing infested material into roots and stems, but these have not proceeded long enough for results to be looked for.

Careful search for comparable nematode infestation of material from trees failing from other affections has proved entirely negative.

Influence of External Conditions.—Cases of the disease have been examined by the writer in all gradations of soil from beach sand to exceedingly stiff clay. No influence on liability to the disease has been detected as proceeding from these variations, or from any unfavourable conditions of growth. The greater number of the examples seen have been in vigorous well-grown trees, and the finest young tree the writer has ever seen, which was growing in deep rich mould where the roots had access to running water, was infested.

A large number of cases were recently seen occurring in a new plantation made seven to eight years ago on virgin soil newly cleared from forest. Most of these were in trees growing under conditions which must be regarded as excellent from every point of view. Rorer's observation as to the tendency of the disease to appear on old sugar land had obviously no application in this and in some other instances seen, except so far that the possibility of nursery infection has not been excluded by the evidence so far collected.

The Origin and Cause of Infestation.—The application of measures adequate for the prevention of the disease requires that the time and manner of infection should be known. The distribution of the infestation in a fully affected tree may be made the basis of reasoning in which certain fairly definite conclusions may be reached, but the validity of these results needs confirmation from the study of cases in the early stages of development, and these have not yet been seen. The disease has previously been regarded as primarily affecting the roots. This view is disposed of by the facts (a) that in all observed instances the infestation of the roots proceeds outwards, (b) that no breeding of the worms takes place there, and (c) that examples are met with of otherwise fully infested trees in which no roots can be found to be affected.

This evidence does not exclude the possibility of infection taking place through one or a few roots which later decay or otherwise escape detection, but there is at present nothing to show that such is the fact.

Analysis of typical cases such as are illustrated in the accompanying plates leads to the following considerations. The red zone in the stem is the base of the infestation, regarded in relation to the invasion of the roots and leaf-stalks The location of the zone has no apparent relation to the anatomy or, so far as is known, to the physiology of the mature stem, and once formed the zone is capable of no lateral expansion, but only of intensification. It is completely developed in that section of the stem which has taken on its permanent form, and becomes less and less complete in density, but for a considerable distance not notably in width, in the upper and still plastic section. It would appear that it is laid down by extension at its upper extremity, as the stem itself is laid down, and matures as the section of the stem it occupies matures. This idea is supported by the known ability of the worms to move freely in the unhardened tissues of the upper stem, and their apparent inability, as evidenced by the continued limitation of the older parts of the infested zone, to occupy fresh territory in developed tissue. It may for the present be assumed that a knowledge of the regional development of the uppermost section of the stem would explain the position occupied by the zone in the fully formed and hardened sections.

From this theory as to the development of the infestation, if it were established there would follow a very important conclusion, namely that infection in all the cases so far seen, since in these the red zone has commenced from the base of the tree, must have taken place at a very early stage, before any part of the stem had so far matured as to prevent infestation.

This immediately suggests the question whether, in fields established according to the usual practice, infection may be regarded as originating from and being confined to the nursery. The sporadic distribution of the early cases, and the frequency of their occurrence on land with no previous record of coco nut cultivation lend some colour to the idea that they are most likely to have originated in the nursery, but the general tendency for the development of the first cases into well-marked groups affords strong evidence of the spread of infection after the trees are planted out. The group of trees Nos. 45-57, with 39 and 53, shown with the dates of failure on the reproduced plan of the Westerhall Plot, affords an illustration of this.

Allowing that infestation begins at an early age and must therefore continue in most cases several, and in some cases many, years, the further question arises as to what development brings about the death of the tree. The infestation of a narrow zone of the cortex of the stem would not appear to involve fatal results, and the injury to the cortex of the roots, while it looks more serious, is not always present when the final and typical symptoms are developed. These begin, outwardly, with the progressive failure of the leaves, and this failure is accompanied by infestation of the leaf-stalks. It is significant that one or

more of the lowest green leaves may escape this infestation and remain healthy in appearance after numerous younger leaves have failed. There is a strong presumption in these cases, which is supported by such examinations as have been made, that the still older leaves, which have reached senility and been shed, were also free from infestation. The conclusion is indicated that invasion of the leaf-stalks marks the entry of the disease to its final stage, and it may, as it develops, be the actual cause of death, but what determines this invasion is not at present clear.

The infestation of the leaf-stalks, it has already been pointed out, begins commonly while they are young and tender and occupy the apex of the stem, and no evidence has been obtained, in the way of visible connexions, that the worms can pass outward from the red zone into the bases of older expanded leaves. Such a connexion can also be absent, over a distance which in one case extended to 9 inches, between the visible seat of infestation in a very young leaf and the apex of the stem to which it is attached. In this case rapid elongation is more likely to have caused the separation, the tissues are in a condition to be easily traversed by the worms, and the possibility is not excluded of their passage between the closely rolled elements of the shoot and subsequent entry into the tissues higher up.

THE CONTROL OF THE DISEASE.

There is a regrettable amount of deduction in the basis of the only counsel as to control which can be given at this stage of the investigation.

There is no record of the recovery of any tree which has shown the outward signs of the disease, nor does there seem any possibility of the successful treatment of a tree once it becomes infested. Prevention, on the other hand, may prove to be feasible.

Of the manner in which the infection is conveyed nothing is at present known. The red ring in two decaying stumps from which the tops had died four to five months before was found to contain very large numbers of the worms in a quiescent but living condition. It is reasonable to assume, in view of the habits of plant nematodes in general, that the soil in the neighbourhood of the diseased trees becomes infested and remains so for a considerable period.

It is conceivable, and sufficiently probable to be the basis of precaution until the facts are known, that the worms may be harboured in the crevices of the fibre of fallen nuts and thus be in a position to enter the young plant after germination. It would therefore be safer to plant nuts that come from areas with no record of infestation, or to use them only when picked from the trees and not gathered from the ground.

Enquiries are being made and information would be welcomed regarding the occurrence or non-occurrence of the disease in fields planted at stake, a point which may have considerable importance.

The Prevention of Field Infections.

It would appear that the entrance of the parasite must be made either by way of a root or between the bases of the young leaves, and of the two methods the latter seems the more likely. For the protection of young trees for the first two or three years after setting out, the writer intends to experiment, when opportunity affords, along three lines :—

(a) Dusting : with powdered sulphur and with mixtures of sulphur with 2 per cent. lead arsenate, and of sulphur with lime.

(b) Spraying : with Bordeaux-nicotine sulphate and Bordeaux-lead arsenate ; with whale-oil soap solution, and with lime-sulphur solution.

(c) The fixing of a slowly soluble or diffusible solid in such a position that rain will wash it down between the younger leaves.

Selection among these measures for extended trials would be made in the first instance on the basis of cheapness, as determined by first cost and persistence. In view of the exposure of new surfaces by the expansion of the leaves, and of the presumed dependence of the migrating worms on moisture supplied by rain, the third method seems the most promising. Trial with soaps and salts used in this manner is suggested to those who wish to experiment.

If, as believed, the trees which ultimately die are previously infested for several years, there is an obvious advantage to be gained by their early detection. With this consideration in view the remaining trees on the Westerhall Plot were tested for the red ring by making a boring near the base of each stem. The results in these cases were negative, but tests on known infested trees appeared to substantiate the feasibility of the method The holes were made with a diameter of $\frac{3}{4}$-inch and a depth of about $2\frac{1}{2}$ inches by means of a brace and bit, and were closed with tarred plugs of deal. Until the after effect of these wounds is seen such trials should be made cautiously, or on the understanding that they are at 'owner's risk.' In making a diagnosis from the extracted chips care must be taken not to mistake for infected tissue the embryonic roots just below the outer fibrous layer (cf. Pl. 5, Fig. 2) which redden very quickly on exposure. A glass slip, a drop of water, and a pocket lens with a magnifying power of 15 or 20 enable the worms to be readily seen and he possibility of mistakes to be eliminated.

The Problem of Infested Trees.

Faced with the disposal of a well-grown palm infested in stem, roots, and leaf-stalks with millions of active worms, the planter has no easy task ; when the number of trees to be disposed of reaches twenty-nine in one week with 100 more waiting, which were the current figures on one estate visited, adequate destruction becomes a practical impossibility. Accepting, however reluctantly, the certainty that the trees under such circumstances will not be destroyed, consideration has to be given to the consequences. On the theory already stated, that infection

takes place only at an early age, the matter is not so serious as it looks, since in a regular field the surrounding trees are too mature for infection by the time the disease is manifested.

On the other hand, if the method suggested above, or any other, can be successfully applied to the discovery of the infestation in its early stages, the complete destruction of any trees so found is important, with a view to preventing the formation of the usual groups of secondary infections.

Summary.

The red ring disease of coco-nut palms (see Introduction) is inferred to be of long duration, and to begin in the first two or three years of the tree's existence.

Outward symptoms of its presence appear only in connexion with the death of the tree, the process of which occupies only a few weeks. These symptoms consist of the dropping of nuts and the progressive discoloration and failure of the leaves, beginning usually, but not invariably, with the oldest leaves, and always progressing towards the centre of the shoot.

Trees which are dying of the disease are invariably infested with a nematode worm, which occupies and breeds in a zone of the stem (the red ring), infests the petioles of the leaves, including those still enclosed in the central shoot, for a distance varying from a few inches to 2 or 3 feet, and is found associated with a discoloured condition of the roots. The red zone is best developed at the base of the stem and diminishes in intensity towards the apex, where it is represented by scattered red dots containing nematodes and their eggs.

The manner of infection and the course of the infestation are not known further than they may be inferred from fully developed examples. It appears certain from the grouping of cases in the field that the disease can be communicated from infested plants to their neighbours.

Present advice is to avoid planting nuts which have lain on the ground in the neighbourhood of infested trees or previous sites of such, and to destroy promptly and as completely as possible infested trees, especially the early cases. The need is pointed out and suggestions are made, for: (a) means of early detection of infested trees, (b) means of protection for young trees in the field.

Note.—With reference to the zones in the stem described on p. 196, it has been found that in some of the trees examined the leaf-spiral ascends to the right, and in others to the left. The direction of the spiral of the vascular bundles in the outer zone of the stem corresponds to that of the leaves. The direction of the second zone of fibres is reversed, and the central core repeats the direction of the leaves.

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NOTE ON ARTIFICIAL INFESTATION.

From Grenada, Mr. J. C. Moore. Superintendent of Agriculture, reports under date September 19, 1919, that trees Nos. 11, 13 and 15, into each of which a fragment of red ring material was introduced by means of an auger hole in the stem during my visit last February, were examined sixty days later and found to be heavily infested with nematodes, with a pronounced red ring from base to apex, and other usual external and internal symptoms. Nos. 12, 14 and 16 in the same row, similarly bored, without introduction of diseased material, survive.

Later infection experiments by Mr. Moore comprised the dropping in the axils of Nos. 23, 24 and 36 of pieces of infested tissue, no wound being made. Of these trees Nos. 23 and 24 have already been found to be in an infested condition. Further, Nos. 59 and 64 were inoculated by cutting out a cube from a petiole, introducing a small amount of infested material and replacing the cube. Of these No. 64 has been examined, and an infestation of numerous leaves and scattered red spots in the trunk found. One of the other trees shown in the plan, No. 37, has died spontaneously from the disease.—W. N.

CORRECTION.—In the legend of Plate V, Fig 1, 'Plate II, should read 'Plate III.'

PLATE I.

Fig. 1. TREE 66, WESTERHALL.
Discoloured and about to die.

Fig. 2. A TRINIDAD EXAMPLE.
Somewhat more advanced.

(Loaned by Board of Agriculture, Trinidad.)

PLATE II.

Fig. 1. RED RING IN STEM OF TREE IN PLATE I, FIG. 2.

(Loaned by Board of Agriculture, Trinidad,)

Fig. 2. A STEM WITH CENTRAL DISCOLOURATION.

(Loaned by Board of Agriculture, Trinidad.)

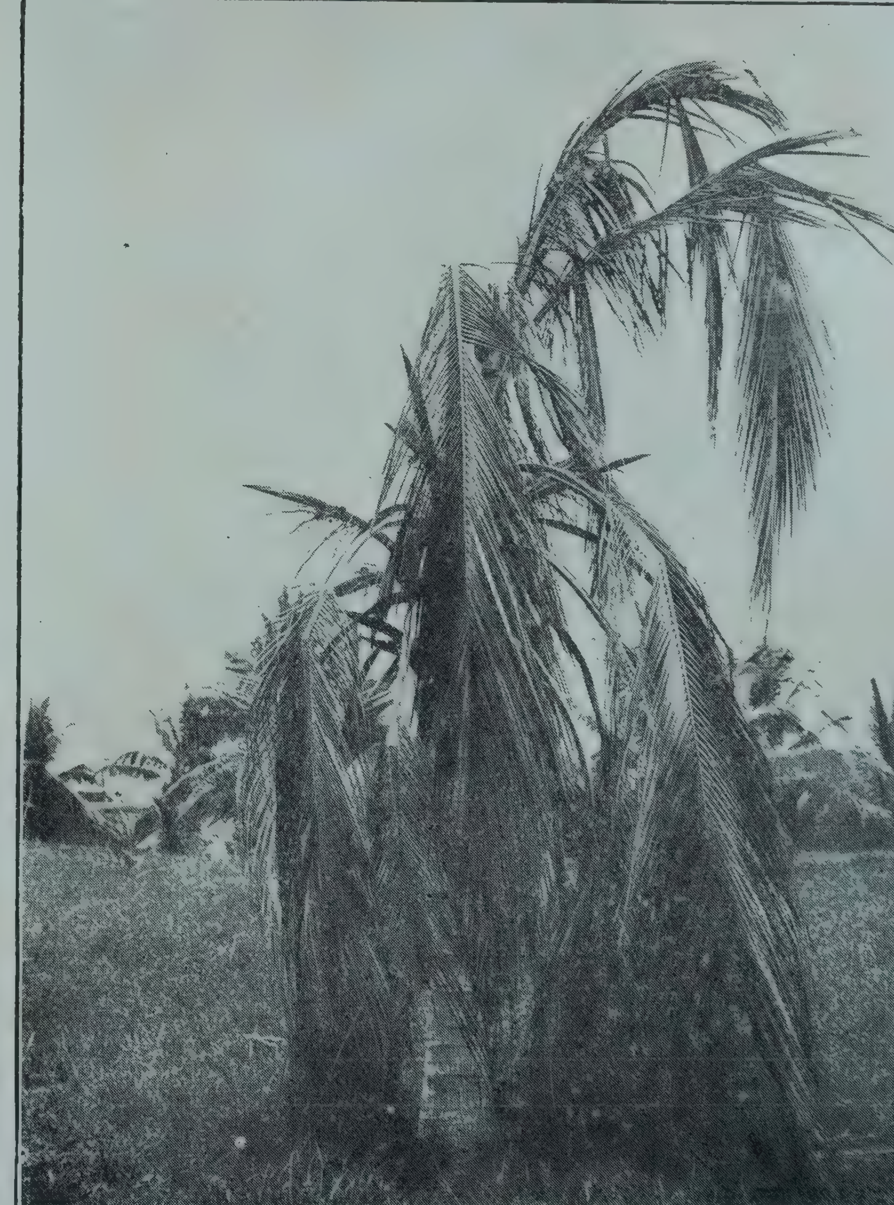


Fig. 3. FINAL STAGE OF FAILURE, WITH PUTRESCENCE OF THE BUD.

(Loaned by Board of Agriculture, Trinidad.)

PLATE III.

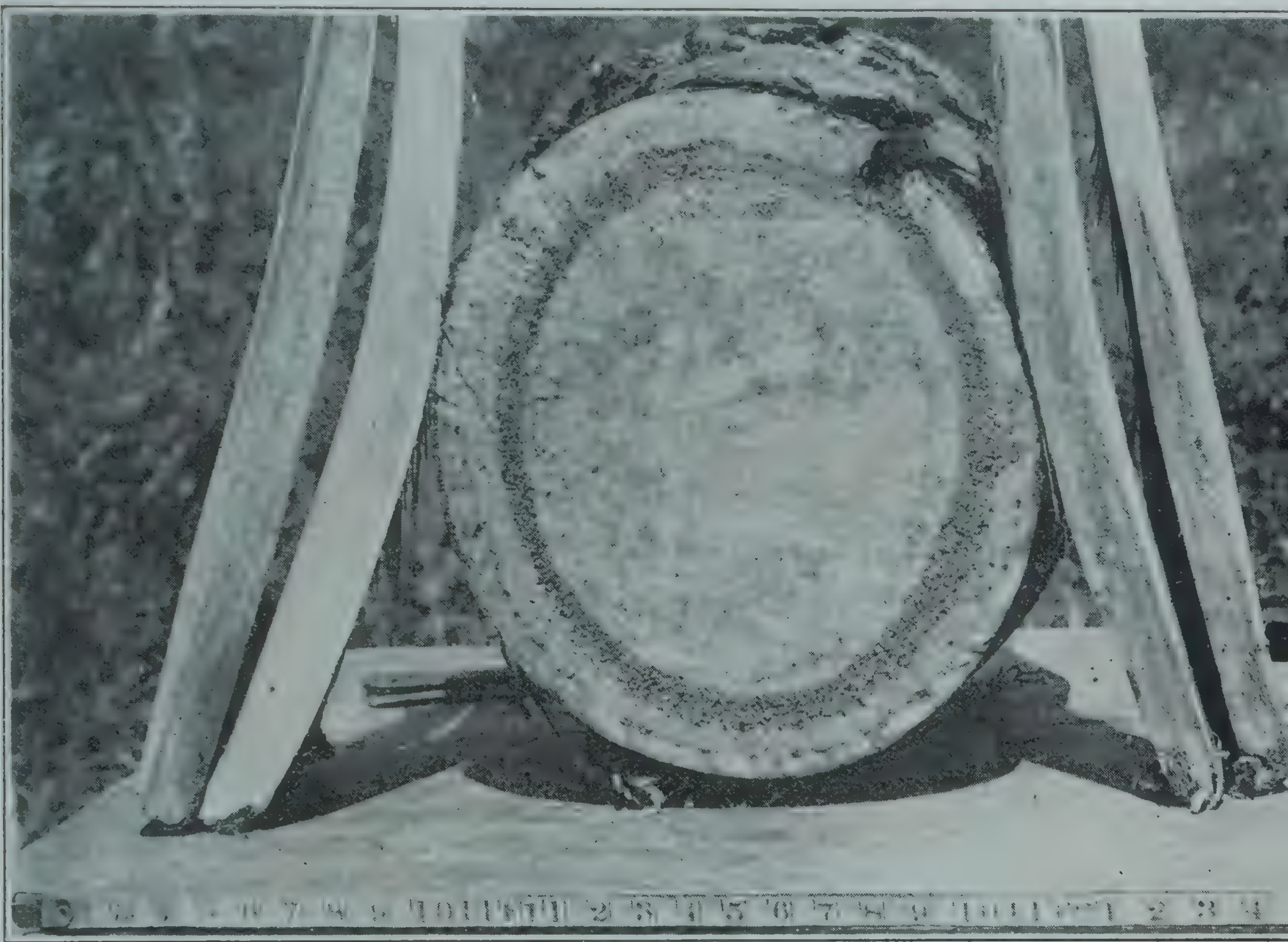


Fig. 1. SECTION OF TREE 66;
Three infested leafstalks and one (the lowest) sound.

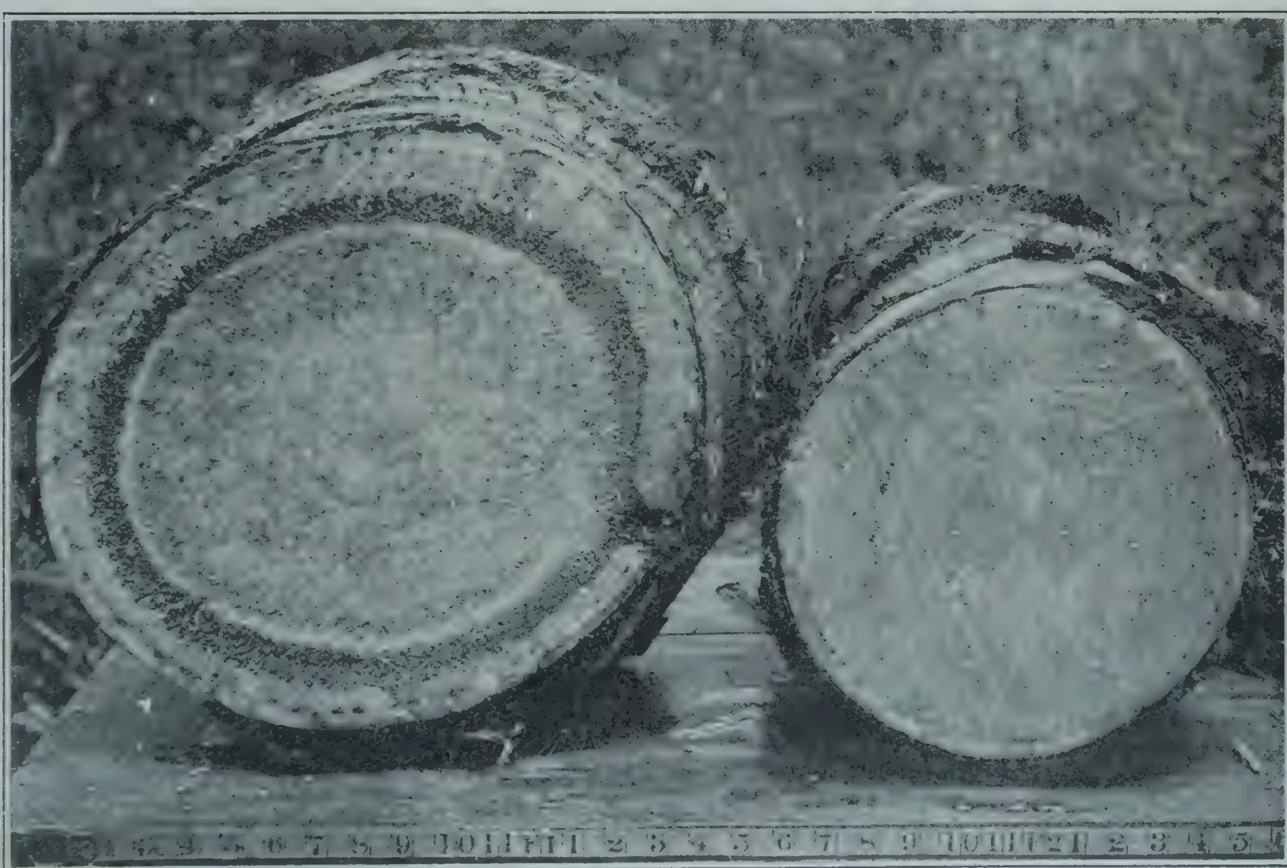


Fig. 2. SECTIONS OF TREE 66 AT 1 FT. 9 IN. AND 3 FT. 6 IN.
Trace of red ring on left of upper section.

PLATE IV.

MEDIAN SECTION OF TREE 62.
Red ring distinct to about 6 ft.; remaining 2 ft. red dotted.

PLATE V.

Fig. 2. LONGITUDINAL SECTION OF SEGMENT IN FIG. 1, NATURAL SIZE.

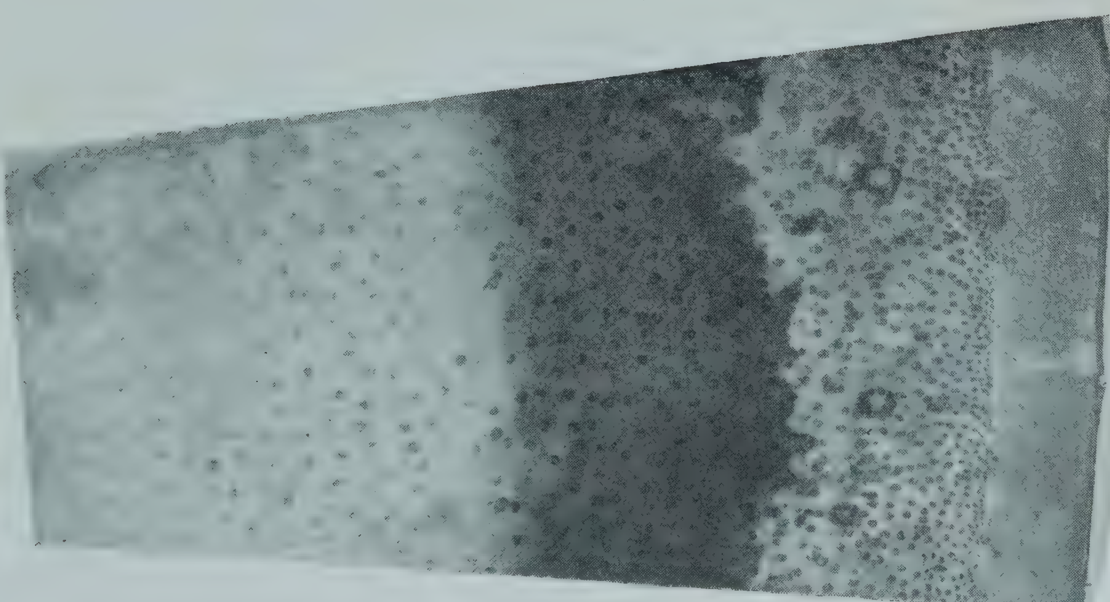


Fig. 1. PART OF LOWER SECTION IN PLATE II, FIG. 2, NATURAL SIZE.

PLATE VI.

LONGITUDINAL SECTION NEAR UPWARD TERMINATION OF RED RING.
(PLATE III, FIG. 2.)

(The line of dormant roots immediately below outer fibrous layer, seen in all the sections, is not infested.)

PLATE VII.

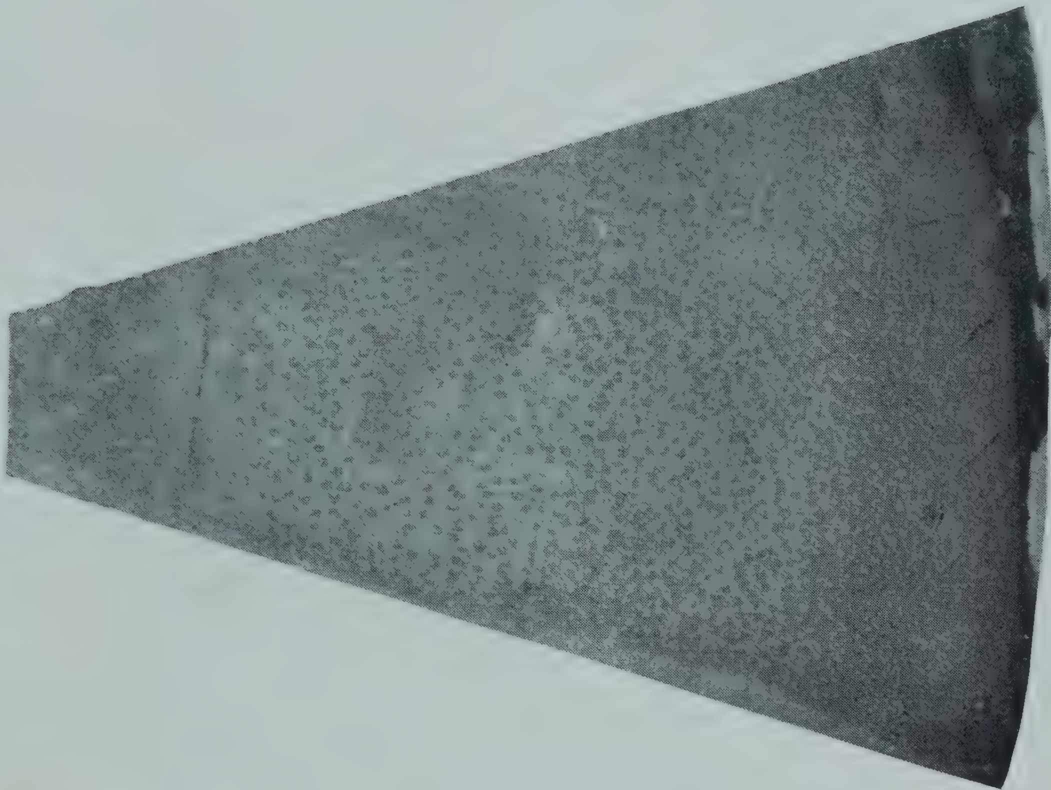


Fig. 1. UPPER SURFACE OF SEGMENT IN PLATE VI.
A few red dots between the vascular bundles.

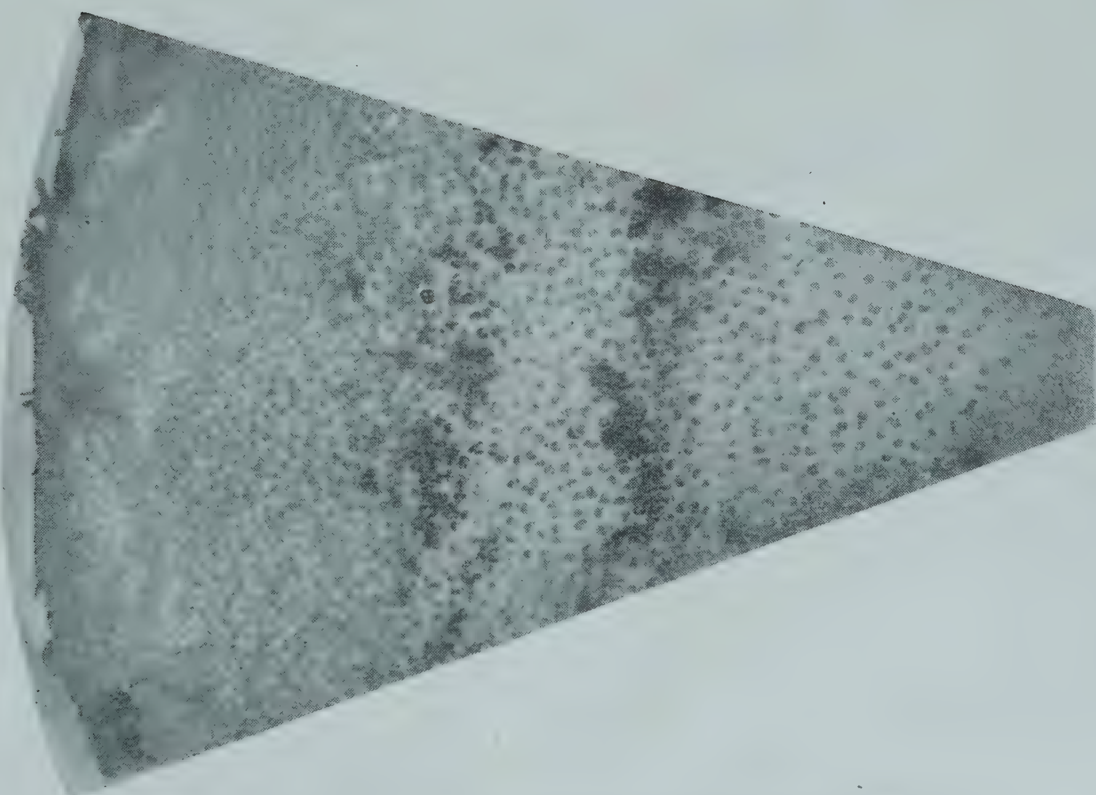


Fig. 2. LOWER SURFACE OF SEGMENT IN PLATE VI.

PLATE VIII.

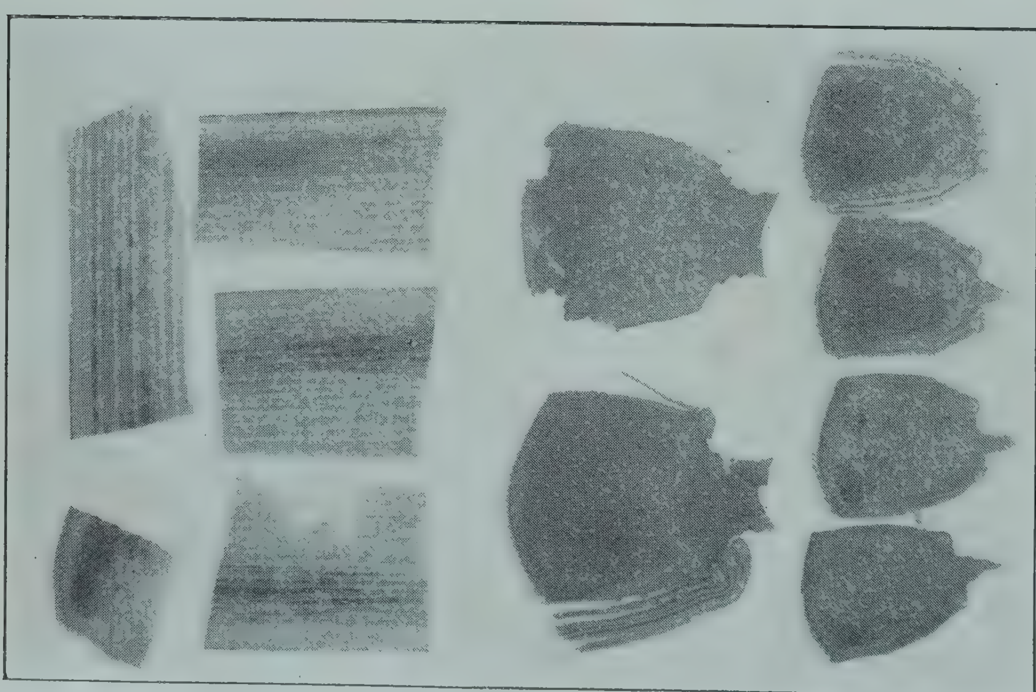


Fig. 1. (INFESTATION OF A VERY YOUNG LEAF (ABOVE) AND OF A YOUNG UNEXPANDED LEAF (BELOW.)

(Natural Size.)

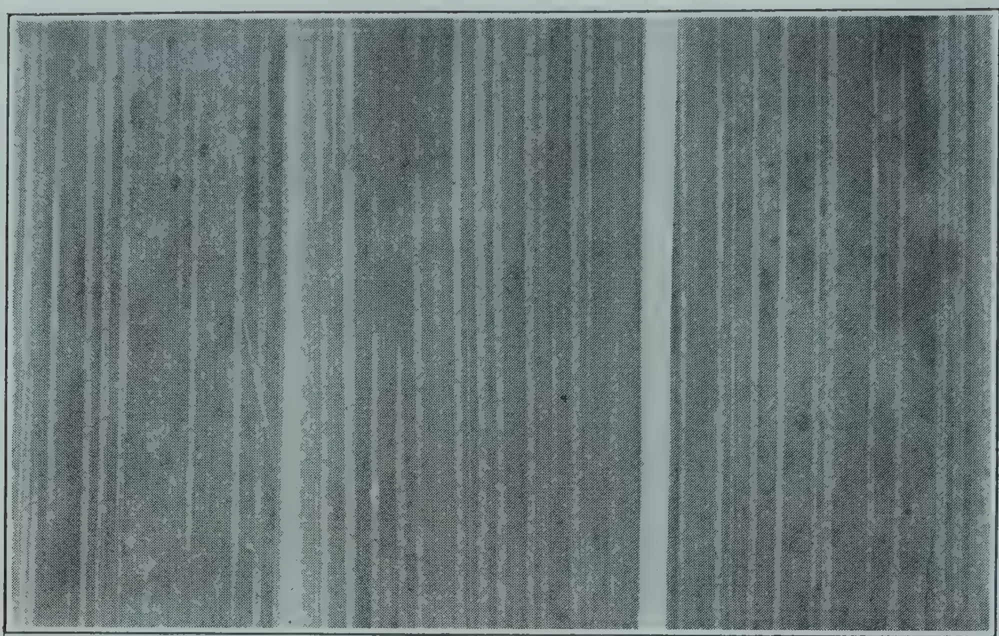
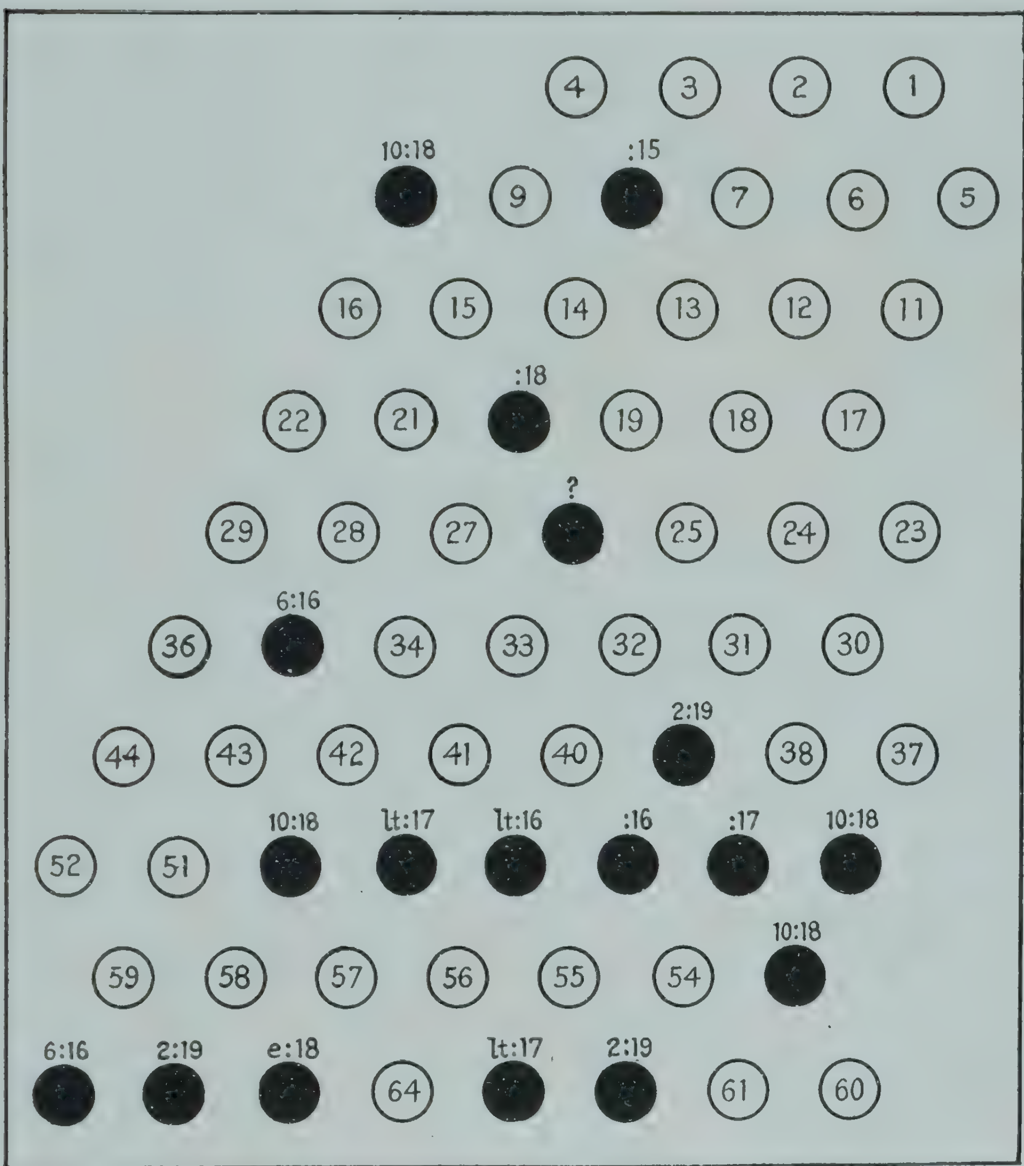


Fig 2. INFESTATION OF THE STALK OF A HALF-GROWN LEAF.

PLATE IX.



LT.—LATE E—EARLY

Plan of the Westerhall Plot, Grenada, February, 1919.

A NEWLY DISCOVERED NEMATODE

(*APHELENCHUS COCOPHILUS*, N. SP.),

CONNECTED WITH A SERIOUS DISEASE

OF THE

Coco-nut palm.*

BY

N. A. COBB,

United States Department of Agriculture.

INTRODUCTION.

The following notes record observations made upon specimens of diseased coco-nut palm, forwarded by Mr. William Nowell, Mycologist to the Imperial Department of Agriculture for the West Indies. Nematised roots of the palm preserved in alcohol, and portions of nematised trunk of the palm preserved in formalin, were almost the sole sources of information with regard to the new parasite. No opportunity has offered for a careful examination of soil adjacent to diseased roots.

This nema belongs to the genus Aphelenchus, Bastian, 1864, and proves to be a new species, for which the name *cocophilus* is proposed. The genus Aphelenchus comprises thirty to forty species, of which a considerable number are serious agricultural pests. Nearly all the species are injurious to plants, but only a fraction of them are known to infest cultivated plants. However, the number of these latter is continually augmenting. Probably a number of the species concerning which at present only anatomical knowledge exists, are also injurious to plants Hence the genus is one of constantly increasing interest to agriculturists. Aphelenchus is closely related to the genera Tylenchus and Heterodera, which include some of the worst pests known to agriculture.

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*When dealing with the material sent for examination Dr. Cobb was under the impression that the disease was mainly a root disease. Some of the remarks and recommendations are made on this assumption. Subsequent work in Trinidad by Mr. Nowell has shown that the disease is mainly one of the stem—a fact which in some measure modifies the recommendations to be made concerning treatment and the prevention of infection.—ED. *W.I.B.*

Description of the Nema.

Aphelenchus cocophilus, n.sp. $\dfrac{1.6}{.9}\cdots\dfrac{8.6}{1.1}\cdots\dfrac{13.}{1.1}\cdots\dfrac{{}^{29}\text{–}68\text{–}{}^{13}}{1.4}\cdots\dfrac{92.}{.9}$ 1. mm

Cuticle and Head : The thin layers of the transparent, colourless naked cuticle are traversed by numerous plain, transverse striæ, all alike except that those near the extremities of the body are somewhat wider (0·6 microns) than those elsewhere. These annules are altered little if any on the lateral fields, where there are only very faint indications of longitudinal wings. There are slightly oblique longitudinal striations due to the attachment of the somatic muscles. The cylindroid neck ends in a subtruncate head, which, at least in alcoholic specimens, is sometimes set off by an almost imperceptible contraction. As the more refractive internal tissues do not approach so near the cuticle in the lip region as elsewhere, there is also contrast in this respect. The lips are completely amalgamated, and the lip region, which is not striated, is flattened in front.

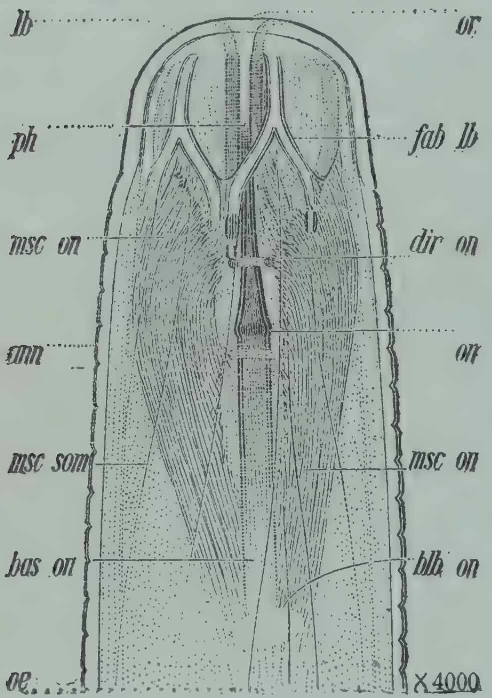

Fig. 1. Head of *Aphelenchus cocophilus*. *lb*, lip region ; *pr*, mouth opening ; *ph*, pharynx ; *fab lb*, frame work of lips ; *msc on*, muscles for thrusting forth the spear ; *dir on*, guide-ring of the spear ; *on*, spear ; *ann*, one of the annules ; *msc som*, one of the muscles of body wall ; *bas on* base of spear ; *blb on*, faint bulbous extremity of spear ; *œ*, œsophagus.

Digestive Tract : No labial papillae have been seen. In the middle of the lip region occurs the minute, pore-like mouth. The simple, rather regular pharynx is narrow and obscure. The spear, which is about one and three-fourths times as long as the base of the head is wide, is difficult of observation ; as a rule, only in the labial region can one distinguish a refractive element indicating the presence of the spear ; while there is a definite posterior 'focus' for the muscles which protrude the very slender spear, there seems to be no very definite basal bulb, or similar structure to which they are attached. There are no amphids or eye-spots. The œsophagus is typically aphelenchoid in form, and presents a distinct, well-developed, elongated, median bulb, one-half as wide as the corresponding portion of the neck. There is also an obscure, finely granular, elongated-clavate, cardiac swelling, one-half as wide as the base of the neck. The median bulb is twice as long as wide, and contains a faint, sub-spheroidal, simple valve somewhat behind its centre. The cardiac swelling consists mainly of the salivary glands, the number of which was not clearly made out, but of which there are probably three. There is no disitinct cardia. Gradually the intestine becomes three-fourths as wide as the body, being built up of cells of such a size that probably only about two are required to build a circumference. The walls of the intestine are rather thin, and its lumen faint. From the very inconspicuous anus, the inconspicuous rectum, which appears to be two to three times as long as the anal body diameter, extends inward and forward. The colourless spherical granules scattered in the intestinal cells are of variable size, the largest being one-eighth as wide as the body ; they are not so arranged as to give rise to a tessellated effect. The conoid tail of the female tapers gradually from far in front of the anus, to a rather blunt, narrow, rounded, unarmed, symmetrical terminus, which has a diameter one-fourth to one-half as great as the anal body diameter. There is no spinneret, and there are no caudal glands or caudal setae. The excretory pore is in the imme-

diate rear of the oblique nerve-ring, which is of medium size, and is accompanied by obscure nerve-cells. The distance from the median bulb to the nerve-ring is about equal to the radius of the corresponding portion of the neck.

Female Sexual Organs: The two rather slender branches of the female reproductive apparatus are out-stretched in opposite directions from the well-developed but rather inconspicuous vulva; the anterior branch serves as an ovary and uterus, while the posterior branch serves as a spermatheca, in which, at maturity, are usually to be seen sperm-cells up to the number of about sixteen. These sperm-cells have conspicuous, finely granular, spherical nuclei one-half to one-third as wide as the body of the female, and by the uninitiated might be taken for eggs. From the vulva the medium-sized vagina passes inward at right angles to the ventral surface about half way across the body. Its walls are not strongly cuticularized. The straight, elongated uterus, which is separated from the ovary by a distinct constriction, is two to three times as long as the corresponding body diameter, and is of such a size as to contain only one or two eggs at a time. These latter are elongated in form, and have thin smooth shells. They are deposited before segmentation begins. The ovary is narrow and tapering, so that its blind end, which lies four to five times as far behind the median oesophageal bulb as this latter does behind the anterior extremity, is one-third as wide as the corresponding portion of the body. The numerous small ova are packed single file in the ovary.

Male: $\frac{1.6}{.8}\ \frac{9.}{1.}\ \frac{13.}{1.}\ \frac{^{45}M}{1.}\ \frac{95.}{1.}\ 1.\ mm$ The posterior part of the male is unlike that of his mate in that the tail tapers differently, the anterior three-fifths of it having nearly the form of a cylinder—i.e. tapering but little to near its middle, where there is usually a sudden decrease of about 50 per cent. in diameter. Thence onward the tail is arcuate, and tapers to the semi-acute terminus. The anus is slightly raised. The tail of the male, at least in alcoholic specimens, is always coiled into a spiral of one to one and one-half winds, the width of the spiral being five to six times as great as that of the body. There is a single testis. The two flat, equal, arcuate spicula lie parallel and very close together, and are not much longer than the anal body diameter. At their widest part, that is at the proximal extremities, they are about one-half as wide as the corresponding portion of the body. As the dorsal elements of the spicula are longer than the ventral elements, the cephala sometimes seem to face almost directly toward the ventral surface of the body. There is a single, rather obscure, somewhat arcuate, rather frail, simple, non-apophysate accessory piece about one-fourth as long as the spicula and arranged parallel to their distal extremities There are no ventral supplementary organs. Two pairs of subventral papillae have been seen, one close in front of the other, just in front of the place where the tail suddenly diminishes in diameter. There appears to be a third subventral pair opposite the middle of the spicula.

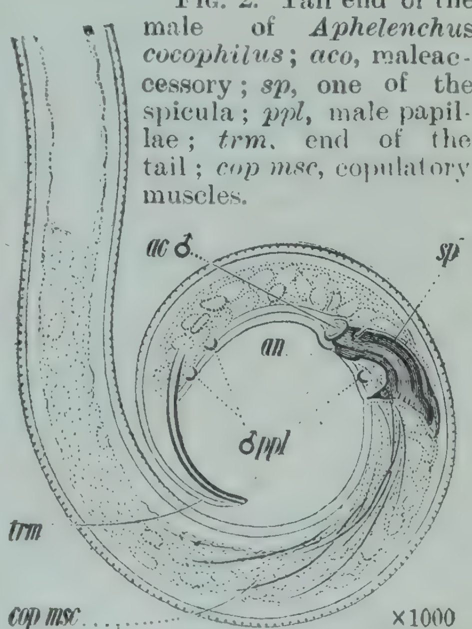

FIG. 2. Tail end of the male of *Aphelenchus cocophilus*; *aco*, maleaccessory; *sp*, one of the spicula; *ppl*, male papillae; *trm*, end of the tail; *cop msc*, copulatory muscles.

Habitat. In roots of the coco-nut palm, Grenada, West Indies. Described from specimens preserved by plunging the roots into 70 per cent. alcohol. The nemas were afterward removed from the root tissues and mounted in glycerine jelly for

examination. Males and females in about equal numbers were found to be abundant in the roots. The tissues just beneath the rind of the roots were softened and discoloured, owing to the infestation. Young specimens were also abundant. The following formula gives the dimensions of the smallest larvae found in the roots.

$$\frac{2.8}{1.7}\quad\frac{18.}{2.}\quad\frac{24.}{2.2}\quad\frac{\text{Y}}{2.5}\quad\frac{91}{1.8}\qquad .37\text{ mm.}$$

The two species of Aphelenchus most closely related structurally to *Aphelenchus cocophilus* are *Aphelenchus elegans*, Micoletsky, and *Aphelenchus helophilus*, de Man. All three species are of about the same general form and size. The following table will serve to indicate various structural differences :—

	COCOPHILUS.	ELEGANS.	HELOPHILUS.
Habitat	...Coco-nut roots	...Water, Lunz, Austria	Soil, Holland, rare.
Tail, female	...Tapers; narrow, blunt ...	Plump, subacute ...	...Rather plump, acute
Eggs ...	...Long ...	...Long ...	...Ellipsoidal (?)
Excret. pore	...Near the bulb	...Not so near the bulb	Near the bulb
Œsoph, bulb	...Elongate ...	...Elongate-ellipsoidal..	Pyriform
Neck ...	...Cylindroid ...	...Tapers some in front	Tapers throughout
Head ...	...Subtruncate	...Rounded ...	...Somewhat rounded
Spear-bulb	...No distinct basal bulb ...	Distinct bulb ...	...Distinct bulb
Spear ...	...Faint, very slender	...Fairly developed	...Fairly developed
Lip-region	...Distinct; no constriction	...Faint; no constriction	...Set off by constriction.

Remedial Measures.

Examination of the literature relating to the diseases of the coco-nut palm shows that the West Indian investigators have already suggested a number of appropriate remedial measures. In this connexion, therefore, reference is made to the previous publications of the Imperial Department. The following are additional suggestions based on the present examinations.

Drainage. It should be borne in mind that water is one of the chief agents in the distribution of root diseases caused by nemas, and that the diseases are therefore distributed to a greater extent downhill than uphill. This applies not only to open ditches of flowing water but to distribution *in* the soil, if the soil is an open one; for there are currents in the soil itself, that is to say, drainage currents that are quite capable of transporting the nemas, and of course always downhill. Possibly it is also worthy of minor note, that diseases caused by nemas, in case the nemas are capable of withstanding desiccation, and are in time brought to the surface of the ground encased in dry, light particles of vegetable detritus, are capable of being transported by the wind, and hence tend, like some insect pests, to spread faster to leeward than to windward. For similar reasons the diseases are more likely to follow the routes of traffic.

Flooding. Many soil-inhabiting and plant-infesting nemas can be drowned; when submerged in water they usually succumb in the course of a few days at most. This suggests the possibility of drowning nemas found attacking the roots of coco-nut palms, and experiments along this line might be advisable. If it turns out that the nemas can be drowned before the palm roots

are seriously injured, this result might lead to the formulation of a method that might prove to be of some economic value. Only experiment can determine this. In this connexion it might also be advisable to test the effect of salt-water. The roots of the coco-nut palm will withstand a considerable degree of salinity, and it may be worth while to determine whether or not salt water would be more injurious to the nemas than fresh water.

Burning. The destruction of all diseased material by fire, or in some other inexpensive way, is strongly advisable. The destruction of orchards should be preceded by an inspection of the roots of the palms it is proposed to sacrifice, to see whether they are actually infested. In case of such drastic action, the inspection might prevent a considerable amount of unnecessary destruction. The inspection should preferably be a microscopic one.

Quarantine. Where legal means exist, plant quarantines can be established that, to a certain extent, will prevent the spread of such diseases as this from one locality to another. In order that quarantine regulations shall work as little hardship as possible, careful attention should be given to the extent to which commerce is thereby hindered. In the case of coco-nuts, there could be little objection, at least from the local point of view, to exporting suspected material to such ports as Liverpool, New York, etc., where there is very slight chance that the disease could cause further injury.

Distribution and Abundance in the Roots. The distribution of the nemas in the roots is correctly described by Mr. Nowell. I find on examining somewhat carefully, that the nemas are most abundant about half way between the outer surface of the root and the central strand. The numerical degree of infestation may be appreciated by considering the fact that, if the roots were uniformly infested at the rate of the part examined, the number of nemas in a root about $\frac{1}{4}$-inch in diameter would be in the neighbourhood of twenty thousand per linear foot. This is a minimum number, for undoubtedly through the necessary manipulation, a number of nemas were destroyed or lost.

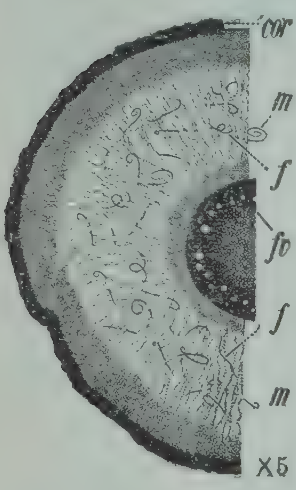

FIG. 3. One-half of a cross-section of a root of coco-nut palm infested with the nema, *Aphelenchus cocophilus*. *cor*, bark or cortex of root; *m* and *f*, male and female nemas infesting the root; *fv*, central fibro-vascular bundle of the root.

Furthermore, it is by no means certain that all the nemas present in the material examined were seen and counted. It is therefore certain that the real number per linear foot would be greater than the calculation indicated, possibly much greater. It was not considered necessary to make more than a roughly approximate estimate.

DESIRABLE EXPERIMENTS.

Resistance to Dryness. An early effort should be made to test the degree to which *Aphelenchus cocophilus* can withstand dryness. It is already known that some species belonging to the

genus Aphelenchus can withstand desiccation for a considerable length of time. At the onset of dryness they enter a comatose state, from which, when again moistened, they revive, and then seem practically as active as ever. This suggests the advisability of caution in collecting coco-nuts for seed. It will be readily conceded that on coco-nut areas infested by this nema, there are plenty of chances of contamination. Should this nema, like many of its confreres, prove resistant to dryness, then old decomposed, nema-infested coco-nut roots and portions of trunk, brought to the surface of the ground, weathered and reduced to fragments, and hence composing a not inconsiderable portion of the surface detritus, may serve as a means of spreading the disease. Such fragments, even when very minute, might easily contain desiccated nemas. (See Fig. 4.) Unless a certain degree of cleanliness and caution is observed, nuts gathered on infested areas might by adhesion easily carry infested dirt, and so afford the nema a chance to spread from one place to another. The history of many diseases caused by nemas shows that they are inadvertently transported in some such way by human agencies to a greater extent than in almost any other. This is a matter in which cultivators and others are shockingly careless.

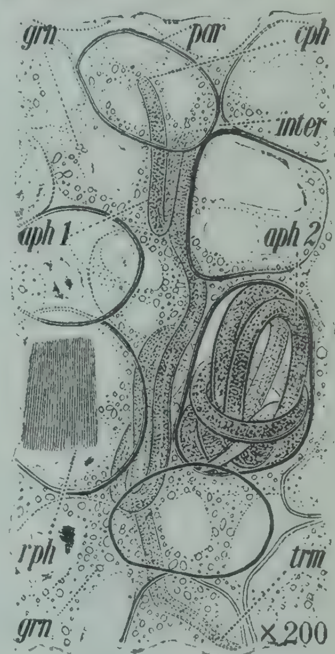

FIG. 4. Sketch showing manner in which *Aphelenchus cocophilus* occurs in the parenchymatous tissue of the trunk of the coco-nut palm. *aph* 1 and 2, two individual nemas as fixed in formalin; *cph*, head end of a nema lying in the intercellular space: *inter*, *trm*, tail end of same; *par*, parenchymatous cell of palm: *rph*, rhaphides in another cell; *grn*, one of the granules in the more or less disintegrated contents of one of the cells. All the palm-cells shown are dead. *The material here shown could be contained in a particle of trash only one one-hundredth of one inch long.*

In general, as little material should be transported from a diseased area to one not diseased as is consistent with the practical conduct of business. A little thought will disclose that this means a great deal more than will at first occur to the average person.

Artificial Infestation. Another important line of experiment should be undertaken at once—that of attempting artificially to infest healthy roots. Diseased roots and soil from about diseased roots should be laid alongside healthy coco-nut roots, in a definite manner at permanently marked locations, and then covered in. These hitherto healthy roots should then from time to time be disinterred and examined for signs of nema infestation. No time should be lost in making this experiment. Positive results from it will not only serve further to establish the nema as the cause of the disease, but will also give information as to the exact method of attack, and the rate of onset.

Length of Life. Infested roots should be stored both in the ground and above ground, and examined from time to time in order to determine how long the nemas will live in such material. The results of this experiment and the preceding will have a very important bearing on the application of a number of remedial measures.

Other possible Hosts. It is very desirable that the roots of other plants growing in the vicinity of diseased coco-nut palms be examined in order to ascertain whether or not they are infested by this nema. The results of such investigation will have a very important bearing on the remedial measures to be taken. It is one matter if the nema is peculiar to the coco-nut palm, and quite a different matter if it also infests plants other than the coco-nut palm. While it is a rule that a parasitic nema infests but one host-plant or only a few related species, there are very striking exceptions to this rule, and no strict deduction can be made from the facts hitherto discovered. From this it follows that in this respect each parasitic nema must be considered by itself. There are enough cases where a given species of nema infests a wide variety of plants to make necessary a very careful search among other tropical plants found growing in the vicinity of the diseased coco-nut palms, in order to determine whether their roots are also infested by this nema. Special plantings under diseased palms might be made in order to investigate this point.

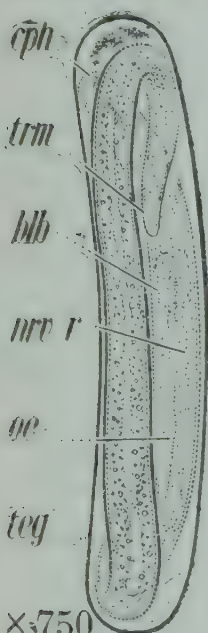

FIG. 5. Egg of *Aphelenchus cocophilus* as found in the tissues of the trunk of coco-nut palm. *cph*, head of embryo; *blb*, œsophageal bulb; *nrv r*, nerve ring; *oe*, œsophagus; *teg*, shell of the egg.

Occurrence free in Soil. It will be important to observe not only the state of infestation of the roots, but also the extent to which the nemas occur in the surrounding soil, and, if found, the stages of their existence during which they migrate into and occupy the soil.

The Nema Enemies. In recent years, the writer's investigations have brought to light the very significant fact that predaceous nemas exist. These predaceous nemas some of them at least, feed upon other nemas, and among these latter are to be found species injurious to agriculture, such as the various species of Aphelenchus. This fact at once raises the important question as to whether these predatory nemas, the Mononchs, Tripylas, etc., may not be utilized to assist in combating the injurious nemas found upon and in the roots of crop plants.

It is therefore strongly advisable that investigators pay particular attention to the presence of any of these predaceous species in soils infested with injurious nemas. It seems not unlikely that the spread, growth and control of certain insect pests may yet be paralleled among the nemas, and that just as certain insect pests have been controlled through the agency of their insect enemies, so injurious nemas may come to be controlled by their nema enemies.

Eggs. The eggs of *Aphelenchus cocophilus* are deposited in the tissues of the host plant where they hatch out and then invade fresh tissues. This method of reproduction is one almost necessarily fatal to the palm, once the infestation has reached the base of the trunk. Combative measures must therefore be largely preventive.

Salivary Glands. The material thus far investigated does not permit of a satisfactory examination of the salivary glands,

As it seems possible that the state of development of these glands is some indication as to the food habits of such nemas as the Alphelenchi, it is advisable that further examinations of these organs be made in *A. cocophilus* and other triplonchs. A notable fact is that, so far as investigations of the triplonchs have proceeded, the salivary glands are more strongly developed in those species which are serious plant pests than in other species. If this proves to be generally true, the state of development of these glands will serve as a guide in judging the possible injuriousness of newly discovered triplonchs, such as this.

THE IMPROVEMENT OF THE YIELD OF SEA ISLAND COTTON IN THE WEST INDIES BY THE ISOLATION OF PURE STRAINS.

PART II.

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INTRODUCTION.

In the first part of the paper (*West Indian Bulletin*, Vol. XVII No. 3) the various morphological characters of the Sea Island cotton plant which could affect the yield of lint per acre were analysed. It was pointed out that by self-fertilization and selection, many distinct strains can be isolated from Sea Island cotton, and that the stable combinations of morphological characters affecting the yield, which emerge as a consequence of strains becoming homozygous through self-fertilization are of varying merit. The object of the cotton breeder is to produce a strain of high grade lint possessing also an optimum association of those morphological characters which affect yield.

The present paper contains a discussion of a further series of St. Vincent results, but is mainly concerned with a detailed analysis of certain data accumulated by Mr. William Robson, during the course of his cotton breeding experiments in Montserrat.

Cotton selection has been carried on in Montserrat for several years, but it was not till 1916 that the method was adopted of using only self-fertilized seed, and of examining certain characters of every individual in a progeny row. Mr. Robson, Curator of the Botanic Station in Montserrat, has recorded the data in his cotton breeding work for the years 1916-18, and the present writer is indebted to him for facilities for analysing the results.

In regard to the data from both Montserrat and St. Vincent, what has been done is to set out briefly the chief conclusions which are to be drawn, to discuss certain correlations of economic importance which have been brought to light, and lastly, to indicate along what lines future work may best proceed.

MATERIALS AND METHODS.

The Montserrat strains divide themselves into three groups. Two of the groups are descended from single plants H.9-23 and H.9 Th., grown in 1915, and the third group from a single plant, D.1, grown in 1916. In each season the plants have been self-fertilized by the copper-wire method. The characters examined were: (a) mean maximum length of pulled lint, in mm. (on 5 seeds), (b) weight of lint per seed in mg. (on 100 seeds), (c) mean seed weight in mg. (on 100 seeds), and (d) number of bolls to the pound of seed-cotton. The last character was not recorded for the individual plants, but only for the whole progeny row. The result is calculated from the weight to the nearest $\frac{1}{8}$-oz. of four lots of 100 bolls picked at random from the row at weekly intervals.

The St. Vincent strains are all descended from single plants grown in 1915. Self-fertilized seed only has been used in the experiments. Weight of lint per seed and mean seed weight have been recorded in the same way as for the Montserrat strains, but no data for the number of bolls to the pound of seed-cotton are available. Mean maximum lint length was not measured on lint pulled from the seed, but by the halo method. A careful comparison of the results obtained by both methods has been made, and indicates that measurements of pulled lint are about 2 per cent. below those obtained by the halo method. The halo method is undoubtedly capable of giving more accurate results.

The following brief statement will make clear the method of numbering the plants and strains. H.9 is a single plant. Seeds of it are sown in a progeny row which is called family H9. The individual plants of the row are numbered H.9-1, H.9 2, H.9-3, etc. If a progeny row from plant H.9-1 is grown, the row is called H.9-1, the individual plants in it being numbered H.9-1-1, H.9-1-2, etc. Thus the line of descent of any strain or single plant is shown by a simple inspection of its number.

This method of numbering is practically identical with that introduced by D. H. J. Webber (1906).

THE RESULTS.

THE MONTSERRAT RESULTS FOR MEAN MAXIMUM LINT LENGTH.

Table I shows the frequency arrays of the Montserrat strains for mean maximum lint length. It is necessary to state, that in Montserrat the plants may show shorter lint in certain seasons owing to drought. The season in 1918 was very dry during the maturing period of the bolls, and the lint is shorter than in previous years. Nothing is advanced here in the way of proof of the above statement, but it has been made fairly

clear that water shortage lowers lint length by Balls's work in Egypt (1915), by a suggestive set of data in a paper by Kelsick (1918), and also by some unpublished data of the writer. Robson has also suggested that drought shortens lint length.

The chief features of Table I are as follows :—

1. In 1916, all three parent strains H.9-23, H.9-Th., and D.1 show relatively little variation in lint length. None of the plants have a lint length of below 49 mm. It is well known that in ordinary commercial fields of Sea Island cotton, plants with lint lengths of 30-33 mm. are not uncommon, and it would seem that the continuous selection for uniform length, carried on by Robson during the several years previous to 1916, had had the effect of eliminating the tendency to produce short lint. According to expectation, no short-linted plants have appeared in subsequent years.

2. The differences in range of the three 1916 strains indicate that, although the tendency to produce short lint had been eliminated, yet it is certain that the strains were not composed of a single genotype. From an inspection of the 1917 data, the present writer advised the selection of the three plants in strain D.1-16 with the longest lint, on the ground that this strain showed a frequency array of range much above any other strain grown that year. Accordingly, two plants were grown on in 1918, producing strains D.1-16-7, and D.1-16 19. While the means for these families are below that of the parent strain, owing probably to drought, they retain the relative superiority in length possessed by the parent type, being higher than any other strain grown in 1918. These two strains may be regarded as a definite advance in lint length, although it cannot as yet be said that they are pure strains.

3. If the longest lint possible were the main thing to aim at in selection, it is probable that selection in strain H.9-Th. would have resulted in the isolation of types with longer lint than any that have been produced. The selection of the six plants in that strain with lint length of 55 mm and above, would conceivably have originated strains of similar range to D.1-16 and its two daughter families, and possibly still higher. The composite nature of H.9-Th. is shown by the fact that selection of the plant with the longest lint in 1917 (plant H.9-Th. 10-4) resulted in 1918 in a family with a longer lint than that of the other strains descended from H.9-Th.

4. Since slight differences in lint length are hereditary, it is obvious that two plants may have precisely the same lint length, but give rise to progeny of widely different means. Thus a lint length of 54 mm. may be the lowest point of a long strain, or the highest point of a short strain. In other words, the somatic expression of length may be different from the genotypic. The measure of the worth of a plant in regard to lint length can only be obtained by expressing it in terms of the average behaviour of its progeny.

5. Bulk samples of all the 1918 strains were sent to the British Cotton Growing Association for report by broker's tests. The strains which have been alluded to above as being definitely longer than the rest are D.1-16-7, D.1-16-19, and H.9-Th-10-4

and of these, D.1-16-7 was unfortunately not sent. The other two are commented on as follows :—

D.1-16-19. 'Fully fine to extra fine, but wasty and irregular in length.'

H.9-Th.-10 4. 'Extra fine, long and silky staple.'

Thus the extreme length of the first of these two strains receives no comment. The length of H.9-Th.-10-4 is mentioned, but it should be statedth at strain H.9 23-2-16, which is 3 mm. shorter than H.9 Th.-10-4, and is therefore one of the shortest types of 1918, is commented on in precisely the same language. It has been clearly demonstrated that these differences in lint length, though slight, are hereditary, and can be maintained from season to season. The inference is, that the methods of judging lint length used by workers in the West Indies are more accurate than those used by the broker.

6. It is no part of the present writer's intention to enter into a discussion as to whether it is desirable to grow the longest lint possible in Montserrat. A 53 mm. cotton, if regular and uniform, would probably be worth more to the spinner than one of 48 mm. The spinner can have which length he prefers, subject to seasonal fluctuation ; but up to the present we are entirely in the dark as to which suits him better.

7. It should be noted, that in the original 1916 families very few plants are at present capable of producing long-linted progeny. If only six plants are available with the probable capacity to develop strains of long lint, and if only two of the plants actually have that capacity, it is evident that the smallest possible chance exists of obtaining by continued selection a strain combining every, or even many, advantageous morphological characters Such a strain could only be developed by a process of synthesis.

8. In general, the Montserrat results show that the lint length of the strains under examination was excellent, even in 1916, and it is probable that subsequent selection has effected no improvement of commercial importance.

THE ST. VINCENT RESULTS FOR MEAN MAXIMUM LINT LENGTH.

The frequency arrays for mean maximum lint length of the St. Vincent strains will be found in Table II. The data are not very full, but it may be inferred that the B.S. strains are constitutionally shorter than all the other strains. The tendency to produce very short lint has also been eliminated from the St. Vincent strains.

THE MONTSERRAT RESULTS FOR WEIGHT OF LINT PER SEED.

The writer has shown in the first part of this paper that lint weight (weight of lint per seed), is one of the most important of the morphological characters affecting yield of lint per acre. It is therefore desirable for a strain to have the highest possible lint weight consistent with high grade lint. In Table III will be seen the frequency arrays for lint weight of the strains of Montserrat.

The most important features of Table III are as follows:—

1. The great variability of the 1916 families is much lessened in the two following seasons. The results admit of a clear interpretation. Self-fertilization has had the effect of reducing the variability of the types, and selection has isolated strains of much higher lint weight than has hitherto been recorded for Sea Island cotton.

The work in Montserrat has proceeded along the same lines as in St. Vincent, but while the present writer, working in the latter island, isolated by selection a strain with a mean lint weight of 50 mg., (V.32-3-1) from a commercial strain with mean value 40 mg., Robson was able to get the mean value of 50 mg. in 1916, and has since obtained in Montserrat the two extraordinary strains H.9-23-2-13 (mean 60 mg.), and H.9-23-2-15 (mean 56 mg.). On the other hand from the strain H 9-Th. has been isolated H.9-Th.-10-4, with the low mean of 38 mg., practically the same as its parent family (41 mg.).

2. The descendants of D.1 have in general much lower value than those from H.9 or H 9-Th. Two very low strains, D.1-16-7 and D.1-16-19 have been isolated. It is, however, clear that had selection for high lint weight been carried on in the descendants of D.1, types with much higher lint weight could have been produced, for it is to be noted that the range of D1-4-10 runs up to 56 mg.

3. From an inspection of the 1917 Montserrat data it was concluded by the present writer, that family H.9 23-2 was genotypically of higher lint weight than any strain bred that year, and it was advised that all plants in that strain of every high lint weight be grown on in 1918. Five strains were accordingly examined in the latter season, and the results show that the strains may be classified into two groups. One group possesses roughly the same mean value as the parent strain. A summary of the five strains under discussion is shown below for convenience :—

Strain.	Lint weight.	Seed weight.	Parent lint weight.
H.9-23-2-1	49	120	68
H.9-23-2-13	60	133	60
H.9-23-2-15	56	133	61
H.9-23-2-16	55	130	59
H.9-23-2-17	52	120	62

The three high strains have high seed weight (130-133). The two low strains have low seed weight (120). It will be shown later, that there is a strong correlation between the lint weight and the seed weight of a group of strains, and it is evident that if strains of high lint weight are required, the seed weight must also be high. A type may be genetically of high

lint weight, but if the seed weight is low, then the high lint weight cannot find expression. This is an excellent example of what is called by Balls 'autogenous fluctuation.' The present writer has observed, that a cross between two types, both of low lint weight, may give rise in F_2 to plants with lint weight higher than either parent. This may be due partially to recombination of Mendelian factors, and partially to the fact that the genetically high lint weight of one parent, which was before unable to find expression owing to the low seed weight, now shows itself in the plants of high seed weight brought in by the other parent.

As seen above, selection of a very high lint weight may give progeny with a comparatively low mean, owing to the complication caused by seed weight. To obtain strains of high lint weight, it is necessary to grow progeny rows from a large number of plants of the highest lint weight obtainable. It is clear that selection must not be confined to one plant.

THE ST. VINCENT RESULTS FOR WEIGHT OF LINT PER SEED.

The frequency arrays for weight of lint per seed of the St. Vincent strains are presented in Table IV. The following are the chief points brought out by this table :—

1. The B.S. strains appear to breed true to a mean of 34-35 mg. Selection of the highest value in B.S.1-53 produced family B.S. 1-53-7, the mean of which was exactly the same as the parental and grand-parental families.

2. In 1917, family V.3-32-3 had a mean of 50mg., and a range considerably above any other family grown that year, if we except the very long-ranged family V.5-61-28, which produced one plant with lint weight 59 mg. An atttempt was made to raise the mean lint weight of V.3-32-3 by selecting a number of plants in it with the highest values. Six families were grown in 1918, but an examination for lint weight of bulk samples of each family showed that no progress has been made. The mean lint weight of the six families ranged from 48 to 50 mg. From the Montserrat results it has been seen that strains of very high lint weight must also have high seed weight. Since the mean seed weight of all families descended from V.3-32-3 is about 120 mg., it is clear that further selection in this strain for a lint weight above 50 mg. is useless. There is no possibility of producing from the St. Vincent material, a strain equal to H.9-23-2-13 (mean 50 mg.).

THE MONTSERRAT RESULTS FOR MEAN SEED WEIGHT.

In Table V will be found the frequency arrays for seed weight of the Montserrat strains. The following are the chief points to be noted :—

1. In 1916, strains H.9-23 and H.9-Th. have an extremely long range, while D.1 has a shorter range.

2. Selection and self-fertilization have led to a reduction in variability, so that in 1918 certain strains appear to be breeding fairly true. Note in particular, families, D.1-16-7 and D.1-16-19, both of which are low, and of approximately the same mean as the parent strain.

3. No strain has been isolated with so many plants of high seed weight as family H.9-Th., and it would seem that the very high seed weights have been eliminated from this type by selecting the lower values. Since a high seed weight is desirable, it is clear that the present case provides an illustration of the chief danger of pure strain work with cotton—elimination of desirable genotypes through ignorance of their good qualities.

The results for the St. Vincent strains are presented in Table VI. No particular comment upon them is required, but emphasis may be laid upon the fact that in general, the seed weight is too low.

THE MONTSERRAT RESULTS FOR NUMBER OF BOLLS TO THE POUND OF SEED COTTON.

In Table VII will be found the Montserrat data for 1917 and 1918 for number of bolls to 1 ℔. of seed-cotton, weight of seed cotton andof lint per boll in grams, and pounds of lint per acre. The strains were grown in single rows, each row being one-hundredth acre in area in 1917, and one-sixtieth acre in 1918. The spacing was 5 feet by 2½ feet in both years. Since only one row was grown of each strain, it is evident that even large differences in yield may be quite devoid of significance, owing to the large probable error involved. A summary of the chief conclusions to be drawn from the data in Table VII is as follows :—

1. The number of bolls to the pound of seed-cotton is another way of expressing the weight of seed-cotton per boll. The value of the latter depends on : (a) the weight of seed per boll and (b) weight of lint per boll. It has been pointed out in the first part of this paper that weight of lint per boll is the resultant of two chief factors : (a) number of seeds per boll, (b) weight of lint per seed. The number of seeds per boll is affected by the number of loculi in the boll and by the number of seeds in each loculus. Both these characters show well-marked hereditary differences in different strains. The weight of lint per seed is correlated with seed weight. If a strain has a high weight of lint per boll, it would seem that it should also have a high weight of lint per seed and a high seed weight. Thus a high positive correlation between lint weight and lint per boll should result. This point will be discussed later.

2. In 1917 the weight of seed cotton per boll ranged from 2·41 gm. in D.1-16 to 3·82 gm. in H.9-23-2, and H.9 Th.-36. There is a 60 per cent. difference in favour of the two latter strains. In 1918, five strains were grown from H.9-23-2. The weight of seed-cotton per boll was increased to 4·02 gm. in H.9-23-2-15. and to 3·91 gm. in H.9-23-2-13 Two strains were grown from D.1-16. Family D.1-16-7 had 2·84 gm. and D.1-16-19 had 2·37 gm. of seed-cotton per boll. Thus the weight of seed cotton per boll is hereditary, and can be increased by selection from a field population. The highest strain in 1918 is 70 per cent more than the lowest.

3. In 1917, the weight of lint per boll ranged from 0·59 gm. in D.16 to 1·12 gm. in H.9-23-2. The difference in favour of the latter is 90 per cent. In 1918, five strains were grown from

H.9-23-2, and in one of these, H.9-23-2-13, the weight of lint per boll was increased to 1·22 gm., representing an increase of 100 per cent. over the lowest for 1918, family D.1-16-19, which had a value of 0·61 gm.

4. From the point of view of the practical cotton breeder, weight of lint per boll is a character of the utmost importance. Weight of lint per boll should be recorded for each plant, on not less than fifteen bolls. It need not, however, be recorded for types of low lint weight, for it will be shown later that high lint per boll is only found in association with high weight of lint per seed. It is interesting to note the following statement of Balls and Holton (1915): 'Since an increase in boll weight would be directly projected as an increased yield, it may be advisable to comment on its nature. No variety of Egyptian cotton at Giza has yet produced more than 2 gm. of seed-cotton per boll under any treatment, or in any season. On the other hand, boll weight was determined, . . . in the Middle Delta, where the weather is cooler, and it was found that the boll weight there rose higher in soil with a deep water table: from 2 grm. with shallow soil it rose nearly to 3 grm. in deep soil.' It is evident that the boll weight of Sea Island cotton is, on the whole, greater than that of Egyptian.

CORRELATIONS.

LINT WEIGHT CORRELATED WITH OTHER CHARACTERS.

(a) *Lint weight of Parent and mean lint weight of Progeny* The coefficient for lint weight of parent correlated with mean lint weight of progeny in forty six Montserrat strains is $0·82 \pm 0·03$, and in twenty-four St. Vincent strains the coefficient has the same value. This indicates that plants of high lint weight tend to produce progeny of high lint weight. The correlation also implies that genetic differences in lint weight are present in the strains under examination, for correlation between parent and progeny in pure strains should be sensibly zero. If strains of high lint weight are desired, selection should begin with as large a number as possible, of plants of high lint weight. The measure of the worth of any particular plant lies in the average behaviour of its progeny. Selection should not be confined to a few plants.

(b) *Lint weight and Lint length.* The coefficient for mean lint length correlated with mean lint weight in a group of twenty-three Montserrat strains is $-0·83 \pm 0·04$. In a group of thirty-six St. Vincent plants selected at random from a field population, the correlation is $-0·55 \pm 0·08$. Both these values are substantial and statistically significant. On the other hand, the coefficient between these two characters in the Montserrat strain H.9-Th.of 1916, is sensibly zero, being $-0·14 \pm ·11$.

It is important to remember that the amount of weight carried by a correlation coefficient depends on whether the data from which it is calculated is a fairly average sample of strains or single plants in general. Thus in calculating correlation between lint length and lint weight, the range of variation of both these characters in the data used should cover the whole range of variation possible in Sea Island cotton. Preponderance of any given com-

bination tends unduly to influence the correlation coefficient in one direction.

Is it permissible to conclude from the two negative correlation coefficients that have been found, that long and high lint weight are antagonistic? The view taken by the present writer is that these negative correlations, although statistically significant, should be looked upon with some degree of caution. Both are based upon a small number of observations, and the presence of only a small number of chance combinations of high lint weight and short lint, or low lint weight and long lint would tend to produce a minus correlation. What is perfectly clear is that no combination of very long lint (above 55 mm.) and high lint weight (above 55 mg) has yet been shown to exist in Sea Island cotton. The longest linted cottons under commercial cultivation are the Superfine Sea Island cottons of St. Vincent. In a typical Superfine plant the lint weight is low (29-35 mg.), and the lint length is from 55-60 mm. It will be pointed out later that there is a high positive correlation between weight of lint per seed and weight of lint per boll, and a positive correlation of simlar magnitude also exists between weight of lint per seed and weight of lint per acre. It has been a matter of common knowledge among planters that Superfine cottons are lower yielders than the ordinary type of Sea Island, and this observation now finds a reasonable explanation in the low weight of lint per seed and consequent low weight of lint per boll of these types. If the lint weight of Superfine were raised by selection, and this could undoubtedly be done, the yield per acre would become greater. If, however, long lint and high lint weight are antagonistic, the danger creeps in of losing the longest linted types, in which case the cottons could no longer be classed as Superfine.

The whole question of the relation of lint length to lint weight should now receive the fullest investigation by a study of a cross between a strain of high lint weight and short lint, and one of low lint weight and long lint.

It may be noted that Balls (1915) does not regard as tenable the dictum that 'the longer the staple of cotton the lower must be the yield.'

(c) *Lint weight and seed weight.* In forty seven Montserrat strains the co-efficient of correlation between these two characters is high and positive. $r = 0{\cdot}73 \pm 0{\cdot}05$. Lint weight and seed weight are necessarily correlated because the amount of lint on the seed is limited by the size of the seed. Fo a seed of a given size there is a maximum possible weight of lint which is less for a small and light seed than for a large and heavy one. Thus the following combinations are possible: heavy seed and heavy lint, heavy seed and light lint, and light seed and light lint. The combination of light seed and heavy lint is a physiological impossibility. It should be noted that the combination of heavy seed and light lint is not represented in the Montserrat strains.

The observation that lint weight and seed weight are correlated is not new. Balls (1909) states that there is a strong correlation between the weight of a seed and the weight of lint which that seed bears. He further states that the cause of variation in ginning out-torn is due to the fact that the corelation between these two characters is incomplete.

(d) *Lint weight and Lint per boll.* The co-efficient for lint weight correlated with lint per boll is high and positive, the value of r being $0{\cdot}90 \pm 0{\cdot}02$ in forty-nine Montserrat strains grown in 1917-18. The existence of this correlation is to be expected since lint weight is one of the chief components of lint per boll (lint per boll = lint per seed × seeds per boll).

(e) *Lint weight and Lint per acre.* For the Montserrat strains of 1917, the correlation coefficient is $0{\cdot}56 \pm 0{\cdot}08$, while in 1918 it is higher, being $0{\cdot}75 \pm 0{\cdot}06$. Thus lint weight is again seen to be of the greatest importance in breeding Sea Island cottons for heavy yield.

LINT LENGTH CORRELATED WITH OTHER CHARACTERS.

Lint length of Parent and mean lint length of Progeny. The correlated coefficient for these two characters for twenty-three Montserrat strains is $0{\cdot}72 \pm 0{\cdot}07$—high and positive. Long-linted strains can only be derived from long linted parents, and as was stated in the discussion of the correlation between lint weight of parent and progeny, the mean of the strain must be used as a guide in selection, and not the character of the individual plant. It may be laid down with a fair degree of certainty, that a strain of long lint cannot be derived from a short-linted parent.

SEED WEIGHT CORRELATED WITH OTHER CHARACTERS.

Seed weight of Parent and mean seed weight of Progeny. The correlation coefficient for these two characters in forty-seven Montserrat strains is high and positive, being $0{\cdot}71 \pm 0{\cdot}05$. Strains of high seed weight originate from parents of high seed weight. The starting point in selection must be a large number of plants of high seed weight. The behaviour of the progeny of such plants will indicate which plants were genetically high, and which were merely high through fluctuation.

LINT PER BOLL CORRELATED WITH OTHER CHARACTERS

Lint per boll and Lint per acre. Since a high positive correlation was found between lint per seed and lint per boll, and also between lint per seed and lint per acre, it might be expected that the correlation between lint per boll and lint per acre would also be high and positive. This expectation is realized for the value of r for twenty-seven Montserrat strains in 1917, is $0{\cdot}54 \pm 0{\cdot}09$. In 1918 it is larger, being ${\cdot}84 \pm 0{\cdot}04$.

LINT PER ACRE CORRELATED WITH OTHER CHARACTERS.

Lint per acre of strain and Lint per acre of parental strain. If all the strains were grown under ideal environmental conditions, and all produced the same number of bolls per plant, it would be easy to pick out the highest yielding strains by estimating weight of lint per boll. The existence of a significant positive correlation between yield of parent strain and yield of daughter strain, $r = 0{\cdot}46 \pm 0{\cdot}12$, indicates that hereditary differences in yield do occur in the Montserrat strains, and that

fluctuation in yield due to soil conditions, etc., have not been great enough to mask hereditary differences in yielding power. It would seem that estimations of yield of strains, even when based on single rows, serve a useful purpose in eliminating very low yielders.

General Considerations.

The results of three years' breeding work with Sea Island cotton have now been discussed, and it is advisable to set forth some general considerations arising from the work as a whole.

In the first place, both in St. Vincent and in Montserrat, it has been shown that Sea Island, as commercially grown, is composed of a mixture of distinct strains, which can be separated by self-fertilization and selection. Both from the point of view of yield and of the commercial value of the lint, these strains are of varying value.

Length of staple would seem to be one of the main factors in determining commercial value. Regularity of staple, which can be judged by estimation of available fibre, is probably largely influenced by amount and distribution of rainfall, and an island like St. Vincent, which usually has an even distribution of rainfall, will perhaps always produce a more valuable product than Montserrat or St. Kitts.

Montserrat can produce a good 48·51 mm. staple, which appears to be entirely satisfactory to the spinner. The negative correlation which appears to exist between lint length and lint weight, and thus also with yield of lint per acre, need not be strongly pressed. Much more evidence is still needed on the question, and it must be borne in mind that statistical constants based on a small number of strains are apt to be misleading. This much may confidently be said. Montserrat has a type of cotton with an amount of lint per boll nearly double that of ordinary c mmercial strains, with a correspondingly heavier yield. If the spinners are led to complain of the spinning properties of this type, it may then be the business of the Agricultural Department to provide another type which can easily be done. Meanwhile, it would seem best to propagate the heaviest yielding type as quickly as possible.

It must be obvious to all who are concerned with cotton breeding work, that the improvement of Sea Island cotton is a peculiarly difficult matter. Before a new strain can be recommended for cultivation on a commercial scale, it must be tested at all possible points. It must possess satisfactory physiological as well as morphological characters. An example will serve to illustrate this point. After four years' work a strain was isolated in St. Vincent which appeared to be desirable in every possible respect. Just when it was about to be put into commercial cultivation, it proved to be undesirable. It was susceptible to bud-shedding, and the seed would not give a good stand of plants owing to some constitutional defect. The inference is obvious. As long as the attempted improvement of Sea Island cotton is carried on by the mass selection method, there is little danger of losing desirable, or of perpetuating undesirable, characters to any great extent. With the adoption of the pedigree selection method

arises the possibility that a desirable character may be dropped out at any point through lack of knowledge as to its importance, and that an undesirable character may be obtained in a homozygous condition.

The work of Sea Island cotton breeding has now become a complex business, and if the work is controlled by those who are not thoroughly familiar with its difficulties, the results produced are quite likely to be disastrous.

In three years in Montserrat and St. Vincent, certain definite results have been achieved. When the whole series of results is scrutinized, it is clear that a good deal of work could have been saved at the outset, if definite ideas had been held as to what was really required. A type of lint weight 60 mg. has been obtained. What are the steps which led to its isolation? In the first place it originated in a family which had a mean and an upward range in excess of the other strains.

Its own range is from 50-68 mg., and it is clear that selection must begin with a number of plants of lint weight not less than 50 mg. In 1915 the present writer made an examination of the lint weight of several hundred plants from a commercial strain. Only two plants out of those examined had a lint weight of 50 or over, and subsequent work has shown that in the descendants of these plants it is impossible to get a mean lint weight of more than 50.

The present strain of ordinary Sea Island cotton grown in St. Vincent is descended from a single plant selected in 1913. Many thousands of plants have been examined in field populations of this strain, and no plant has been seen with lint weight above 55 mg. It would appear useless to attempt to obtain from St. Vincent field population, by ordinary methods of selection, a strain of mean lint weight 60 mg. such as has been developed in Montserrat. The particular combination of genetic factors necessary for the production of very high lint weight has evidently been eliminated from the St. Vincent material. Selection in St. Kitts has probably resulted in the same state of affairs, for the mean lint weight of the commercial type grown in that colony is even lower than that grown in St. Vincent.

One method is left whereby the lint weight of St. Vincent and St. Kitts can be improved, namely by hybridization with the Montserrat strain H.9-23-2-13 (lint weight 60 mg.). There is a tendency among cotton workers to regard with suspicion methods of cotton breeding involving artificial hybridization. In the past, attempts have been made to evolve new types of cotton more suited to West Indian conditions, by hybridizing Sea Island cotton with West Indian indigenous cottons. All these attempts were unsuccessful, the reason being that in the second generation of such crosses appeared an enormous number of different types. None of these resembled either parent, and none possessed the particular combinations sought for. These crosses, however, involved inter-specific types, differing markedly in every measurable character. What would happen if hybrids were made between two pure strains of Sea Island, the characters of which were definitely known? The second generation would be composed of Sea Island plants possessing various combinations of parental characters, resembling in appearance an ordinary

field population, and probably not more heterozygous. Since selection at present begins with complex natural hybrids of unknown parentage, it is reasonable to suppose that better results will be obtained if the starting point for selection is a group of second generation plants out of a cross between two pure strains, provided that this cross is made with the deliberate intention of producing certain combinations.

The remarks which have just been made on the advisability of introducing artificial hybridization into cotton selection work must not be taken to imply that the work of isolating desirable new strains from commercial material must cease. The fullest possible advantage must be taken of the great variation existing in that material, and isolation of desirable new strains should be prosecuted with the greatest energy. It is clear that the Montserrat work has suffered to some extent from the fact that three strains only have been worked with. By a fortunate circumstance, families H.9-23 and H.9-Th. contained valuable material, but it is quite possible that these might have been as inferior as D.1 has proved to be.

Having disposed of these preliminary considerations, it is now possible to set out a practical method for the improvement of Sea Island cotton which will give valuable results in a comparatively short time, and by which the dangers alluded to above as arising in a pure strain work are not likely to occur.

A Method of Improving Sea Island Cotton.

1. From a commercial field of Sea Island cotton or from the F_2 of a cross between two S.I. strains, select about 300 plants. Examine the plants for the following characters :—

(a) Mean maximum of lint (on five seeds).
(b) Weight of lint per seed (on 100 seeds).
(c) Seed weight (on 100 seeds).
(d) Weight of lint per boll (on fifteen bolls).

No plant should be selected of lint length less than 50 mm., lint weight less than 47 mg., seed weight less than 130 mg., or lint per boll of less than 0·90 gm.

2. Grow all the selected plants in progeny rows of twenty plants in the following year. At the time when the first bolls are opening, make an examination of the rows, rejecting all rows which are undesirable from the general vegetative point of view. Bearing in mind the fact that number of bolls per plant is of the highest importance from the point of view of yield, a row may be rejected for the following reasons :—

(a) Greater susceptibility to the Angular leaf spot disease than its neighbours, (b) obvious liability to shedding of either bolls or buds, (c) inability to produce a good stand.

Gather a bulk sample of seed-cotton consisting of 200 bolls from each of the remaining rows. Record the characters as follows :—

(a) Lint length on twenty-five seeds.
(b) Weight of lint per boll.
(c) Weight of lint per seed.
(d) Seed weight.

The last three characters can be recorded by weighing the seed- cotton, and then weighing the lint, after hand-ginning. The only test of the inherent worth of a plant is the average behaviour of its progeny, and the results of the bulk sample test will enable the observer to eliminate all the poorer types. Select the best six rows, and examine the characters of each plant, in the same manner as stated in 1. No row should be selected with mean lint length of less than 48 mm., lint weight less than 50 mg., seed weight less than 130 mg., or lint per boll of less than 1.10 gm. After the six rows have been examined, the best three hould be self-fertilized

3. Plant progeny rows in the next year of twenty plants, of all plants in the best three rows. Again at the fruiting stage eliminate any rows which are undesirable vegetatively, and examine bulk samples form the remaining rows as in the previous year. elect the two best rows from each group for examination of individual plants. At this stage the strains should be in a condition of relative purity, and either or both can be selected for propagation on a large scale.

The principles which are followed in the above method of selection may be summed up thus :—

1. Full advantage is taken of the great variation existing in commercial Sea Island cotton, and in the F_2 generation of Sea Island crosses.

2. The bulk sample method of examination gives an approximately correct idea of the average behaviour of all plants in the row, thus enabling the observer to eliminate types which show themselves genotypically inferior.

3. Practical use is made of the correlations which exist between :—

(a) Weight of lint per seed and weight of lint per boll.
(b) Weight of lint per boll and weight of lint per acre.
(c) Weight of lint per seed and weight of seed.

4. The unit of selection is not the individual plant, but the mean of its progeny.

GENERAL SUMMARY.

Experiments have shown that by self-fertilization of commercial Sea Island cotton many distinct strains can be isolated. From the point of view of both grower and spinner, these strains are of varying merit, and thus the isolation of strains superior in yielding capacity to the types commercially grown becomes a matter of importance.

Since the quality of the lint produced by the grower must be satisfactory to the spinner, the question of the effect of selection on lint length isdealt with at some length in this paper. The following are points of importance which it is necessary to emphasize :—

1. Short-linted plants can be eliminated easily and rapidly from the commercial crop by the adoption of the pedigree culture method.

2. Slight differences in lint length, weight of lint per seed, seed weight, and weight of lint per boll are hereditary, and are maintained from season to season.

3. The yield of Sea Island cotton can be increased by selecting plants possessing certain combinations of morphological characters.

4. Particular attention should be paid to weight of lint per seed, and seed weight. Weight of lint per seed is correlated with weight of lint per boll, and with weight of lint per acre.

5. Types of high seed weight must be grown because the maximum weight of lint per seed can only occur if the seed weight is also at the maximum.

6. There is a strong correlation between parent and mean of progeny in respect of the characters lint length, lint weight, and seed weight. The character of a plant therefore affords some guide to the kind of progeny it will produce, but in general, the inherent worth of a plant can only be judged in terms of the average behaviour of its progeny.

7. Lint length and lint weight are possibly negatively correlated, but there is a need for further investigation of the subject. No strain exists at the present time possessing the combination of long lint (above 55 mm.) and high lint weight (above 55 mg.).

8. The chief danger of pure strain work with Sea Island cotton is that valuable combinations of Mendelian factors may be permanently lost, unless full attention be given throughout the period of selection to all the morphological and physiological characters bearing on yield.

9. The particular combination of Mendelian factors which has given rise to the Montserrat strain of lint weight 60 mg., appears to have been eliminated from the St. Vincent and St. Kitts commercial cottons.

10. The yield of St. Vincent and St. Kitts cottons can undoubtedly be increased by crossing them with the heaviest yielding Montserrat strain, and the whole question of artificial hybridization in relation to cotton breeding is discussed at length.

11. A method of improving Sea Island cotton is set forth which will give practical results in a comparatively short space of time.

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Table I.

MEAN MAXIMUM LENGTH OF LINT.

Frequency Arrays for Montserrat Strains, 1916-1918.

Family.	Year.	Parent.	Lint Length in M.M.												Mean.
			45	46	47	48	49	50	51	52	53	54	55	56	
D1	1916	–						1	3	12	14	4	1		53
D1-4	1917	53							7	9	4				52
D1-4-10 ...	1918	51			2	27	19	2							49
D1-4-14 ...	1918	52				2	10	6	2						49
D1-5	1917	53						1	3	13	2	1			52
D1-5-8 ...	1918	51				1	2	12	5						50
D1-11	1917	52						1	3	13	2	1			52
D1-16	1917	53									9	8	2	1	54
D1-16-7 ...	1918	55							3	13	7	3	1		53
D1-16-19 ...	1918	56					1	–	–	8	8	14	2		53
D1-25	1917	53							10	6	3	–	1		52
D1-26	1917	53							1	11	4				52
D1-30	1917	53							3	13	4				52
D1-30-4 ...	1918	52				1	4	9	6						50
D1-36	1917	54							4	8	5				52
D1-36-7 ...	1918	52				1	9	5	5						50
H9-23	1916						1	2	7	10	15	4			52
H9-23-2 ...	1917	53							7	9	4				52
H9-23-2-1 ...	1918	53	1	–	2	6	3	14	4	1					49
H9-23-2-13 ...	1918	52		3	18	19	10								48
H9-23-2-15 ...	1918	52			5	17	13	13	2						49
H9-23-2-16 ...	1918	53		1	11	12	11	5							48
H9-23-2-17 ...	1918	52		4	9	19	11	4	3						49
H9-23-3 ...	1917	53						2	7	4					51
H9-23-10 ...	1917	53							6	12	2				52

TABLE I.—*Continued.*

MEAN MAXIMUM LENGTH OF LINT.

Frequency Arrays for Montserrat Strains 1916-1918.

Family.	Year.	Parent.	Lint Length in M.M.												Mean.
			45	46	47	48	49	50	51	52	53	54	55	56	
H9-23-11 ...	1917	52						1	8	10	1				52
H9-23-11-7 ..	1918	53				1	10	8	1						50
H9-23-12 ...	1917	54							6	12	2				52
H9-23-12-3 ..	1918	52			1	3	5	7	4						50
H9-23-14 ...	1917	53						1	12	5					51
H9-23-14-1 ...	1918	51			5	10	5								48
H9-23-14-3 ...	1918	51				11	9								49
H9-23-18 ...	1917	52						5	12	3					51
H9-23-23 ...	1917	53						7	10	3					51
H9-23-27 ...	1917	52						4	10	6					51
H9-Th ...	1916								1	12	12	8	4	2	53
H9-Th-1 ..	1917	53							2	13	5				52
H9-Th-1-1 ..	1918	52				1	8	9	2						50
H9-Th-1-4 ...	1918	53			10	19	18	3							48
H9-Th-5 ...	1917	54							3	16	1				52
H9-Th-5-15 ..	1918	51				5	13	1	1						49
H9-Th-10 ...	1917	53							4	9	6	1			52
H9-Th-10-4 ...	1918	54				1	6	4	4	2	3				51
H9-Th-11 ...	1917	53							13	7					51
H9-Th-22 ...	1917	52						1	11	7	1				51
H9-Th-22-4 ...	1918	51			3	10	7								48
H9-Th-36 ...	1917	52						1	3	13	3				52
H9-Th-36-9 ...	1918	52				7	8	5							49
H9-Th-37 ...	1917	54							2	10	8				52
H9-Th-37-5 ...	1918	52			2	6	10	2							49

Table II.

MEAN MAXIMUM LENGTH OF LINT.

Frequency Arrays for St. Vincent Strains, 1917-18.

Family.	Year.	Parent.	Lint Length in Mm.														Mean.
			43	44	45	46	47	48	49	50	51	52	53	54	55	56	
BS1-33 ...	1917	–	2	2	2	3	3	2	–	1							46
BS1-53 ...	1917	–		1	2	1	1	4	6	4	2						48
BS1-53-7 ...	1918	50				1	11	12	13	6	1						48
V1-9-7 ...	1917	–								5	3	3	2	1			51
V1-9-19 ...	1917	–			1	–	–	3	5	3	3						49
V1-9-22 ...	1917	–					1	2	3	5	8	5	2				51
V1-9-22-18 ...	1918	50				1	6	6	10	9	1						49
V1-9-27 ...	1917	–					1	3	2	5	6	2					50
V1-9-35 ...	1917	–						1	3	8	6	2					50
V1-9-37 ...	1917	–									4	5	6	2	1		53
V1-9-37-5 ...	1917	53						7	13	11	10	–	1				50
V3-32-3 ...	1917	–							1	4	–	3	6	6	1		52
V3-32-3-1 ...	1918	52						6	–	2	1						49
V5-56-33 ...	1917	–		1	–	1	1	2	2	5	–	1	–	1			49
V5-61-31 ...	1917	–			2	–	1	4	1	4							48
V5-61-18 ...	1917	–							2	1	7	7	11	8	1	1	53
V5-61-24 ...	1917	–				1	–	6	5	16	6	9	3				50
V5-61-24-17 ...	1918	50				1	3	7	10	9	3	2	1				49
V5-61-28 ...	1917	–							1	–	6	5	8	–	1		52
V13-1-18 ...	1917	–					1	3	3	1	1	–	1				49
V13-1-20 ...	1917	–					1	–	2	9	7	6	5	1			51
V13-1-20-30 ...	1918	–							1	10	1						50

TABLE III.

MEAN WEIGHT OF LINT PER SEED.

Frequency Arrays of Montserrat Strains, 1916-18.

Family.	Year	Parent.	Weight of Lint per seed in Mg.														Mean.
			29	32	35	38	41	44	47	50	53	56	59	62	65	68	
D1	1916			1	1	9	9	9	5	1							42
D1-4	1917	14					1	6	9	2							45
D1-4-10 ...	1918	48					4	18	16	8	3	1					46
D1-4-14 ...	1918	51					4	7	7	2							45
D1-5	1917	49				3	6	7	4								43
D1-5-8 ...	1918	45		1	1	1	2	10	5								43
D1-11 ...	1917	42				3	6	7	4								43
D1-16 ...	1917	37	4	6	6	3											33
D1-16-7 ...	1918	31	2	5	9	9	2										35
D1-16-19 ...	1918	31	3	11	13	4	2										34
D1-25 ..	1917	39		1	8	5	3										36
D1-26 ...	1917	45				2	7	5	1								42
D1-30 ...	1917	48		2	5	6	6	1									38
D1-30-4 ...	1918	45				6	11	3									41
D1-36 ...	1917	46			1	4	9	–	1								40
D1-36-7 ...	1918	41			2	10	6	2									39
H9-23 ...	1916	50			1	–	–	4	8	5	11	7	–	2			51
H9-23-2 ...	1917	56							1	2	6	5	4	1	–	1	56
H9-23-2-1 ...	1918	68					5	2	4	12	4	3					49
H9-23-2-13 ...	1918	60								2	1	8	13	18	7	1	60
H9-23-2-15 ...	1918	61							1	3	10	22	11	3			56
H9-23-2-16 ..	1918	59								4	13	20	1	1			55
H9-23-2-17 ...	1918	62				1	–	2	7	10	14	14	2				52
H9-23-3 ...	1917	61							1	4	3	3					52
H9-23-10 ...	1917	54						6	3	8	3						48

TABLE III.—(*Concluded*).

MEAN WEIGHT OF LINT PER SEED.

Frequency Arrays of Montserrat Strains, 1916-18.

Family.	Year.	Parent.	Weight of Lint per seed in Mg.														Mean.
			29	32	35	38	41	44	47	50	53	56	59	62	65	68	
H9-23-11 ...	1917	56						2	4	9	4	-	1				50
H9-23-11-7 ...	1918	52						1	1	10	2	5	1				52
H9-23-12 ...	1917	52				1	3	8	7	1							45
H9-23-12-3 ...	1918	51					2	4	6	7	1						47
H9-23-14 ...	1917	48				1	2	7	5	2	1						50
H9-23-14-1 ...	1918	53					1	1	6	3	7	1	1				50
H9-23-14-3 ...	1918	50							6	4	7	3					51
H9-23-18 ...	1917	54					2	4	5	6	2	1					48
H9-23-23 ...	1917	51				2	3	6	7	1	1						45
H9-23-27 ...	1917	52					3	3	7	2	5						47
H9-Th ...	1916					4	2	7	7	11	3	3	1				48
H9-Th-1 ...	1917	50					1	1	5	7	5	-	1				50
H9-Th-1-1 ...	1918	58							2	5	7	5	1				53
H9-Th-1-4 ...	1918	53					2	2	11	8	13	11	3				51
H9-Th-5 ...	1917	51				1	3	6	6	3	1						46
H9-Th-5-15 ..	1918	50					5	6	3	5	1						45
H9-Th-10 ...	1917	37			1	5	8	3	3								41
H9-Th-10-4 ...	1918	36		1	5	7	5	1	1								38
H9-Th-11 ...	1917	50					8	8	2	2							44
H9-Th-22 ...	1917	51					4	3	6	6	1						47
H9-Th-22-4 ...	1918	52						4	10	5	-	1					48
H9-Th-36 ...	1917	54						2	8	7	2						48
H9-Th-36-9 ...	1918	52					1	1	3	8	5	1					50
H9-Th-37 ...	1917	53						2	3	6	7	2					51
H9-Th-37-5 ...	1918	54						1	6	8	4	-	1				50

Table IV.

MEAN WEIGHT OF LINT PER SEED.

Frequency Arrays for St. Vincent Strains 1916-18.

Family.	Year.	Parent.	23	26	29	32	35	38	41	44	47	50	53	56	59	Mean.
BS1	1916	43			2	–	–	1	–	1						35
BS1-33 ...	1917	29				2	4	–	1							35
BS1-53 ..	1917	30		1	1	3	6	4	1							35
BS1-53-7 ...	1918	42	1	–	–	9	21	14	1							35
BS5	1916	35			3	4	17	6								35
BS6	1916	36			3	6	6	6								34
V1-9	1916	42							1	3	3	3				46
V1-9-7 ...	1917	43						3	2	5	4					43
V1-9-19 ..	1917	51								2	3	6	1			49
V1-9-22 ...	1917	47							1	8	4	6	2			47
V1-9-22-18 ...	1918	55							3	15	16	5	1			46
V1-9-27 ...	1917	43					1	3	3	7	2	1	1			42
V1-9-35 ...	1917	49						1	3	3	7	2	1			46
V1-9-37 ...	1917	46						1	2	4	6	2	1			46
V1-9-37-5 ..	1918	–						1	3	19	7	3				45
V3-32 ...	1916	45						4	4	4	7					43
V3-32-3 ...	1917	47								1	7	3	4	2		50
V3-32-3-1 ..	1918	56									1	7	1			50
V5-56 ..	1916	42					1	3	1	1	1	1				41
V5-56-33 ...	1917	–							2	3	2	4				46
V5-56-34 ...	1917	–							1	3	5	3				47
V5-61 ...	1916	48					2	1	5	4	5					43
V5-61-18 ..	1917	–					1	2	6	4	8					43
V5-61-24 ..	1917	47							5	10	11	4	2			46
V5-61-24-17 ...	1918	53							6	18	12	1				45
V5-61-28 ...	1917	–				1	1	–	2	7	3	1	1	–	1	42
V13-1 ...	1916	44						3	8	6	1	1	1			43
V13-1-18 ...	1917	52								4	2	3	1			47
V13-1-20 ...	1917	51				2	–	1	3	8	5	5	1			45
V13-1-20-30 ...	1918	–							7	13	1	–	1			41

TABLE V.

MEAN SEED WEIGHT.

Frequency Arrays of Montserrat Strains, 1916-18.

Family.	Year.	Parent.	Mean Seed Weight in Mg.																		Mean.
			88	93	98	103	108	113	118	123	128	133	138	143	148	153	158	163	168	173	
D1	1916							3	2	2	12	6	7	1	2						130
D1-1 ...	1917	139				1	–	2	3	5	2	5	1								125
D1-4-10 ...	1918	118			4	5	5	16	8	10	2										114
D1-4-11 ...	1918	132					1	6	3	3	4	2	1								121
D1-5 ...	1917	122					6	7	2	3	1										116
D1-5-8 ...	1918	113				2	–	2	5	5	3	3									121
D1-11 ...	1917	127					6	7	2	3	1	–	1								116
D1-16 ...	1917	113	1	2	3	4	8	2													104
D1-16-7 ...	1918	96	1	5	1	9	3	6	1	–	1										105
D1-16-19 ...	1918	107	2	7	14	4	3	2	1												99
D1-25 ...	1917	115		1	3	2	3	6	5												109
D1-26 ...	1917	131					1	5	7	1	1										117
D1-30 .	1917	127		1	4	6	3	2	3	1											107
D1-30-4 ...	1918	119		1	1	5	6	6	1												108
D1-36 ...	1917	142				4	1	5	1	3	1										113
D1-36-7 ...	1918	105				2	9	6	2	1											101
H9-23 ...	1916							1	2	5	4	8	4	5	4	2	2	1			136
H9-23-2 ...	1917	146							1	3	4	3	4	5							133
H9-23-2-1	1918	136			1	4	2	3	5	6	5	–	1	2	1						120
H9-23-2-13	1918	136						2	1	8	9	12	7	7	4						133
H9-23-2-15	1918	143						1	2	6	10	14	9	5	2	1					133
H9-23-2-16	1918	143						1	2	9	13	3	8	3	1						130
H9-23-2-17	1918	142					1	10	19	12	3	5									120
H9-23-3 ...	1917	152							2	1	3	3	1								128
H9-23-10 ...	1917	144					2	3	8	5	1	–	1								119

TABLE V.—(*Concluded.*)

MEAN SEED WEIGHT.

Frequency Arrays of Montserrat Strains, 1916-18.

Family.	Year.	Parent.	Mean Seed Weight in Mg.																		Mean.
			88	93	98	103	108	113	118	123	128	133	138	143	148	153	158	163	168	173	
H9-23-11 ...	1917	113						8	7	2	2										118
H9-23-11-7	1918	119					1	2	8	5	2	2									120
H9-23-12 ...	1917	138				2	1	8	5	1	2	–	1								16
H9-23-12-3	1918	136			1	1	3	7	6	2											111
H9-23-14 ...	1917	130				2	4	4	3	3	1	1									115
H9-23-14-1	1918	123				3	2	8	3	3	1										114
H9-23-14-3	1918	123				1	4	1	7	3	4										118
H9-23-18 ..	1917	135			1	1	1	5	6	2	1	2	1								118
H9-23-23 ...	1917	131			2	2	5	3	3	1	3	–	1								111
H9-23-27 ...	1917					4	2	5	2	2	3	1	–	–	–	1					117
H9-Th ...	1916						1	1	–	1	4	7	1	9	5	1	4	2	–	2	142
H9-Th-1 ...	1917	130							2	7	4	4	1	2							128
H9-Th-1-1	1918	142						2	4	5	4	4	–	1							125
H9-Th-1-4	1918	131					2	6	8	11	7	3	3								123
H9-Th-5 ...	1917	117				1	–	2	2	3	2	8	2								127
H9-Th-5-15	1918	126				1	2	6	4	3	3	–	1								118
H9-Th-10 ...	1917	131					3	7	3	4	1	–	2								118
H9-Th-10-4	1918	123						7	4	4	3	1	1								121
H9-Th-11 ...	1917	143						2	3	6	2	5	2								126
H9-Th-22 ..	1917	142					1	1	2	4	3	6	2	1							128
H9-Th-22-4	1918	134					2	4	5	5	5	1									120
H9-Th-36 ...	1917	156								1	3	5	4	3	2						136
H9-Th-36-9	1918	131						1	1	3	5	[illegible]	4	3							132
H9-Th-37 ...	1917	[illegible]								3	4	4	5	4	2						136
H9-Th-37-5	1918	136						1	2	5	2	6	4								129

TABLE VI.

MEAN SEED WEIGHT.

Frequency Arrays for St. Vincent Strains, 1916-18.

Family.	Year.	Parent.	Mean Seed Wt. in Mg.												Mean
			93	98	103	108	113	118	123	128	133	138	143	148	
BS1	1916	–						1	1	1	1	1			128
BS1-33 ...	1917	–						4	1	–	2	1			125
BS1-53 ..	1917	–						4	5	2	4	1	1	1	128
BS1-53-7 ...	1918	125	1	2	5	11	11	6	6	3	–	1			113
BS5	1916	117		1	4	10	4	2	7	2	1	1			115
BS6	1916	116		1	2	9	1	2	3	2	1				113
V1-9	1916	111								1	2	4	2	1	138
V1-9-7 ...	1917	132				1	3	4	2	4					126
V1-9-19 ..	1917	132				1	1	4	2	4					121
V1-9-22 ..	1917	136						7	2	4	4	4	1		128
V1-9-22-18 ...	1918	136				1	3	6	14	7	10				124
V1-9-27 ...	1917	142			1	–	1	1	6	3	2	3			126
V1-9-35 ...	1917	138						4	2	2	4	4	1		129
V1-9-37 ...	1917	137						1	3	4	5	2	1		130
V1-9-37-5 ...	1918	–				1	4	7	10	6	4	1			123
V3-32 ...	1916	129		1	1	2	4	5	2	4					117
V3-32-3 ...	1917	124		2	–	–	7	4	2	1					115
V3-32-3-1 ...	1918	121					2	2	4	1					120
V5-56 ..	1916	103						2	3	1	–	1			124
V5-56-33 ...	1917	127				1	1	1	1	4	3				125
V5-56-34 ...	1917	140					2	1	2	3	3	1			126
V5-61 ...	1916	120			2	3	3	4	5	1					116
V5-61-18 ..	1917	116				2	7	10	1	1					116
V5-61-24 ...	1917	119			2	3	5	9	9	5					118
V5-61-24-17 ...	1918	114	1	–	6	16	12	3							109
V5-61-28 ...	1917	121			1	1	5	7	2	1					116
V13-1 ...	1916	–			2	2	–	7	4	3	1	–	1		120
V13-1-18 ...	1917	143									6	4	1		136
V13-1-20 ...	1917	132					1	–	5	10	6	2	2		129
V13-1-20-30 ...	1918	126					1	5	8	5	2	1			124

TABLE VII.

Showing Number of Bolls to 1 lb. of Seed Cotton, Weight of Seed Cotton per Boll, Weight of Lint per Boll, and Weight of Lint per Acre, in the Montserrat Strains of 1917-18.

Family.	Year.	Bolls to 1 lb.	Seed cotton per Boll, gms	Lint per boll, gms.	Lint per acre, lbs.
D1-4	1917	141	3·15	0·85	445
D1-4-10	1918	146	3·11	0·90	527
D1-4-14	1918	145	3·13	1·09	66[illegible]
D1-5	1917	160	2·84	0·77	427
D1-5-8	1918	153	2·97	0·78	563
D1-11	1917	177	2·56	0·67	465
D1-16	1917	188	2·41	0·59	410
D1-16-7	1918	160	2·84	0·74	593
D1-16-19	1918	192	2·37	0·61	461
D1-25	1917	180	2·52	0·65	429
D1-26	1917	160	2·84	0·75	452
D1-30	1917	174	2·61	0·68	451
D1-30-4	1918	170	2·67	0·73	512
D1-36	1917	166	2·80	0·73	538
D26	1917	142	3·20	0·96	615
H9-23-2	1917	119	3·82	1·12	727
H9-23-2-4 ...	1918	138	3·29	0·95	544
H9-23-2-13 ..	1918	116	3·91	1·20	774
H9-23-2-15 ...	1918	113	4·02	1·19	617
H9-23-2-16 ...	1918	119	3·82	1·13	
H9-23-2-17 ...	1918	134	3·39	1·02	581
H9-23-3	1917	129	3·52	1·00	479
H9-23-10	1917	130	3·49	1·02	488
H9-23-11	1917	129	3·52	1·03	529
H9-23-11-7 ...	1918	128	3·55	1·06	643

TABLE VII.—(*Concluded.*)

Showing Number of Bolls to 1 lb. of Seed Cotton, Weight of Seed Cotton per Boll, Weight of Lint per Boll, and Weight of Lint per Acre, in the Montserrat Strains of 1917-18.

Family.	Year.	Bolls to 1 lb.	Seed cotton per boll, gms.	Lint per boll, gms.	Lint per acre, lb.
H9-23-12	1917	137	3·31	0·93	504
H9-23-12-3 ...	1918	132	3·44	1·01	537
H9-23-14	1917	138	3·29	0·92	651
H9-23-14-1 ...	1918	124	3·67	1 12	781
H9-23-14-3 ...	1918	136	3·34	1·01	628
H9-23-18	1917	147	3·09	0 89	524
H9-23-23	1917	145	3·13	0·89	467
H9-23-27	1917	149	3·20	0·92	427
H9-Th-1	1917	123	3·70	1 02	514
H9-Th-1-1 ...	1918	123	3·70	1·09	639
H9-Th-1-4 ..	1918	129	3·52	1 05	651
H9-Th-5	1917	135	3·36	0·88	508
H9-Th-5-15 ...	1918	129	3·52	0·98	609
H9-Th-10	1917	141	3·22	0 83	527
H9-Th-10-4 ...	1918	136	3·34	0 81	468
H9-Th-11	1917	132	3·11	0·89	442
H9-Th-22	1917	122	3 72	0·99	450
H9-Th-22-4 ...	1918	128	3·55	1·01	595
H9-Th-36	1917	119	3·82	1·00	529
H9-Th-36-9 ...	1918	115	3·95	1·09	660
H9-Th-37	1917	124	3·67	0·99	503
H9-Th-37-5 ...	1918	127	3·58	1·00	641
St. K. 14	1917	157	2·89	0·89	597
St K. 18	1917	159	2·86	0·79	462

COTTON AND THE PINK BOLLWORM IN EGYPT.

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At the request of the Egyptian Government, Mr. Ballou visited Egypt for the purpose of making a critical investigation of the methods being employed there for the control of the pink bollworm. Mr. Ballou was in Egypt from September 1916 to February 1918. At the termination of his work in that country he presented to the Government a report on his investigations into the control of the pink bollworm, with an appendix dealing with the development of the cotton industry and the causes which had operated to bring about a steady reduction in the average yield per acre. The present paper is in the nature of a review of the report and the appendix.

In the ordinary course, a review such as this would be published after the original papers had appeared, but in view of the difficulties in the matter of publication which have prevailed, the Egyptian Government has consented to this paper being published without waiting for the appearance of the Report.—Ed. *W.I.B.*

PART I.

THE INDUSTRY'S DEVELOPMENT AND FALLING RATE OF YIELD.

Cotton was known in Egypt from early historical times, probably having been spun and woven in that country before it was grown there as a crop. A good deal of uncertainty exists as to the date when it was first cultivated on a commercial scale. This may have been in the thirteenth or fourteenth century.

At the beginning of the nineteenth century, cotton held a very small place among the crops grown in Egypt. About 1820, Mahommed Ali, the Viceroy, believing that cotton might be made a valuable asset in Egyptian agriculture, undertook to stimulate the cultivation of this plant.

At this time there was no export of raw cotton, the small quantity produced being spun and woven in the country. In Upper Egypt, cotton was grown as a perennial, often occupying the land for eight to ten years without replanting. In the Delta it was mostly grown as an annual.

Mahommed Ali endeavoured to find improved varieties, and appears to have commenced his work by using the seeds of a cotton plant found growing as an ornamental in a garden in Cairo. This was known as Jumel cotton, and this variety, together with the strains which were produced as a result of its crossing with one or another of the many introduced varieties, provided the cultivated cotton of Egypt for a number of years.

From the beginning of Mahommed Ali's interest in cotton growing, this industry became a Government monopoly. Government agents determined the area to be planted in cotton in each locality, and the Sheik el Balad, or village headman, apportioned amongst the villagers the areas which each must plant. When the crop was gathered, the product could be sold only to Government agents at prices fixed by Government. No grants were made for this cultivation, but the payment of taxes might be delayed by cotton cultivators, and the amount of the tax deducted from the price received for the cotton when the crop was delivered.

Mahommed Ali caused wells and waterwheels to be established to provide for irrigation for cotton cultivation, but these had to be paid for out of the proceeds of the crops. For many years cotton was an unprofitable crop for the farmer.

Jumel cotton was grown at first as a three-year perennial. There were many subsequent introductions of seed, the principal of which were that of the Sea Island from Georgia and Florida, and of the Brazilian or Peruvian from South America.

During the first thirty years of this renewed cotton cultivation, cotton remained unprofitable, ranking about ninth in importance amongst the crops of the country. The amount of labour required to irrigate one feddan of cotton through the season would provide for the irrigation of several acres of other crops. During this period, it appears that the yields per acre were very low, the best yields from the best lands probably not being over $2\frac{1}{2}$ kantars per feddan,* or 255 lb. per acre.

By 1849, the State monoply of cotton growing had been abolished. The export duty which had formerly stood at 10 per cent. had been gradually reduced to 1 per cent., and this had the effect of somewhat stimulating interest in this crop. The total crop for the country, which in 1820 is recorded as being less than 1,000 kantars, had reached in 1850 the very considerable figure of 384,000 kantars.† During the next ten years, the annual crop ranged from about 500,000 to 600,000 kantars, showing that there was a steady and consistent growth of the industry. The American Civil War gave a great stimulus to cotton growing in Egypt,

*The unit of land measures in Egypt is the feddan, which is equal to 1·038 acres: the English acre equals 0·9633 feddan. The yields given in this paper in kantars per feddan may be read as hundreds of pounds of lint per acre for approximate equivalents. For example, 2·50 kantars per feddan equals 255 lb. per acre, and 5·80 kantars per feddan equals 596 lb. per acre.

†The kantar of cotton represents an amount of seed-cotton which will give 100 rotls of lint. In recent years 315 rotls has been the weight of the kantar of seed-cotton. The ginned cotton is also sold in kantars of 100 rotls each. A cotton variety which has a high ginning outturn yields more than a kantar of lint from the kantar of seed-cotton, and this feature is not pleasing to the grower who feels that the ginner has the advantage in the bargain; while, on the other hand, the varieties which have a low ginning outturn, give less than the 100 rotls of lint per kantar of seed-cotton. If such varieties are grown on a large scale, the ginners are liable to vary the kantar of seed-cotton to yield 100 rotls of lint.

The kantar of 100 rotls equals 99·05 lb. or 44·928 kilograms. The English pound avoirdupois equals 1·01 rotls.

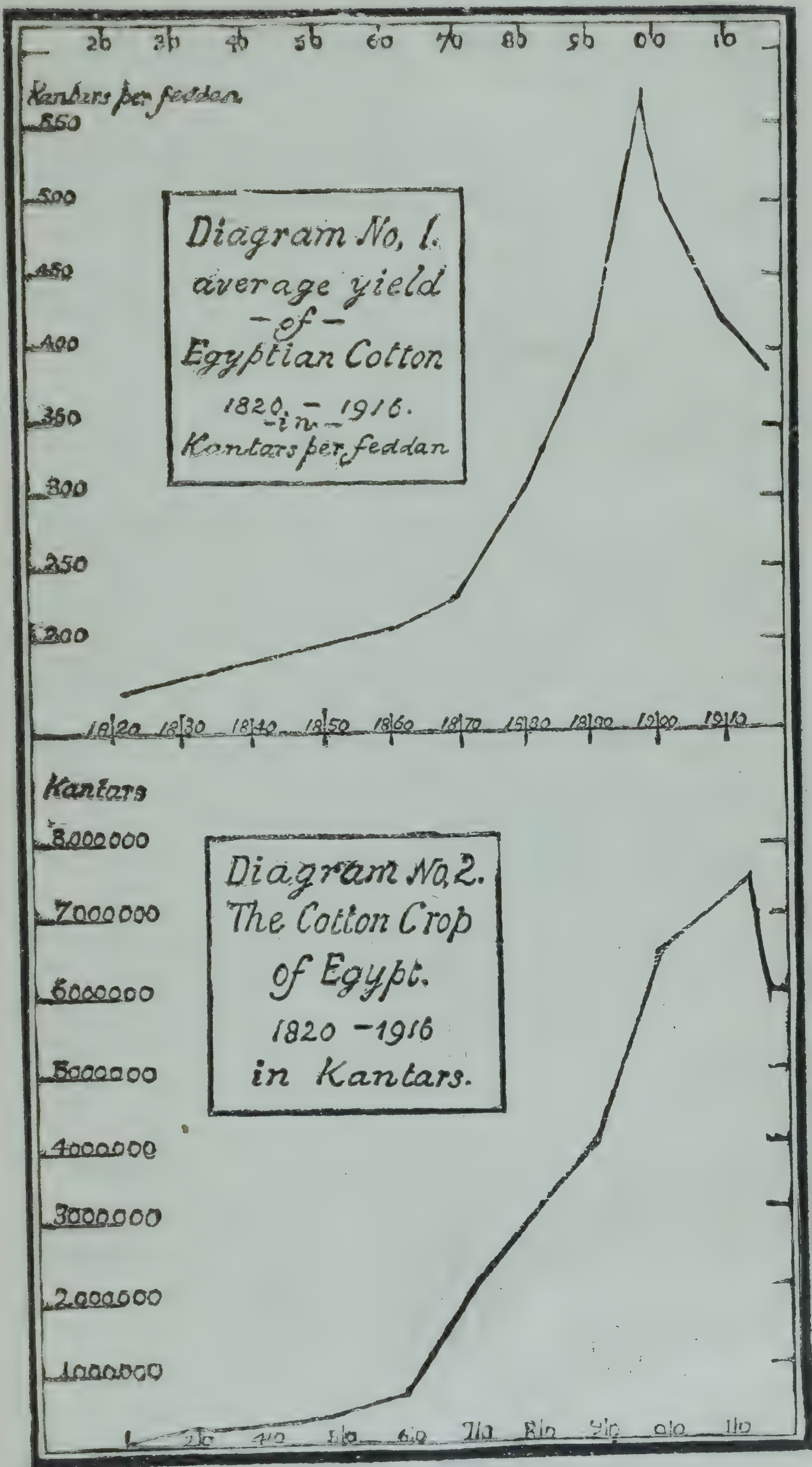
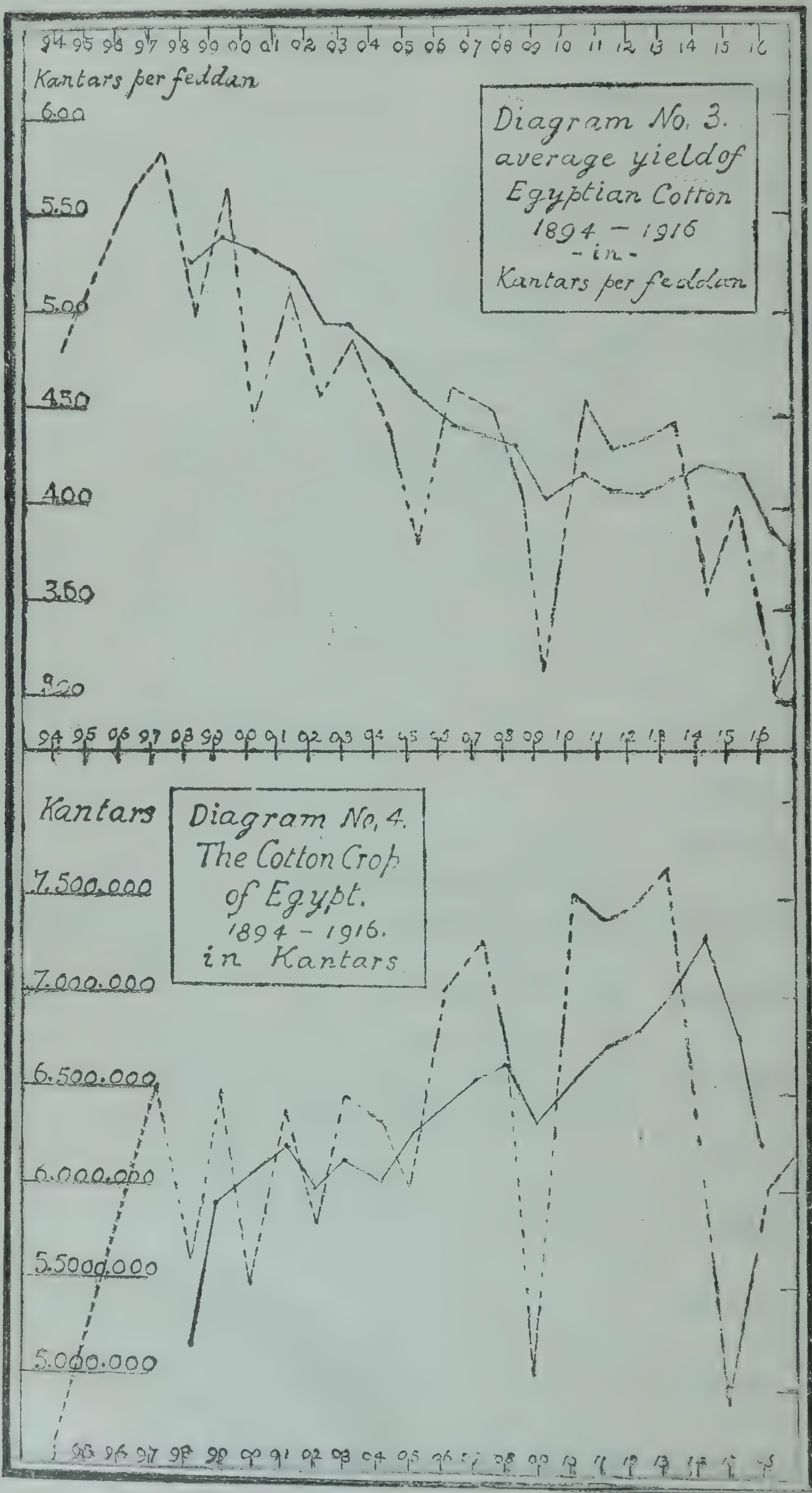


Diagram No. 1.
average yield
- of -
Egyptian Cotton
1820 - 1916.
- in -
Kantars per feddan
Kantars per feddan
550
500
450
400
350
300
250
200
1820
1830
1840
1850
1860
1870
1880
1890
1900
1910
Diagram No. 2.
The Cotton Crop
of Egypt.
1820 - 1916
in Kantars.
Kantars
8000000
7000000
6000000
5000000
4000000
3000000
2000000
1000000


Kantars per feddan
Diagram No. 3.
average yield of
Egyptian Cotton
1894 – 1916
– in –
Kantars per feddan
6.00
5.50
5.00
4.50
4.00
3.50
3.00
Kantars
Diagram No. 4.
The Cotton Crop
of Egypt.
1894 – 1916.
in Kantars
7.500.000
7.000.000
6.500.000
6.000.000
5.500.000
5.000.000

the crop rising from 596,200 in 1860, to 2,000,000 in 1864, after which there was a reaction, and the amount produced fell off considerably, and did not rise above the 2,000,000 mark until 1871.

There appear to be no available figures for the area under cotton cultivation in Egypt previous to 1870, in which year some 719,000 feddans yielded nearly 2,800,000 kantars of cotton, the average yield per feddan being given as 2·73 kantars.

In 1820, there was no Egyptian cotton variety, and the peasants had no knowledge of the agricultural practices involved in the cultivation of the crop. Facilities for irrigation were poor, and the summer water-supply was uncertain.

During the early part of this period, the Jumel and Sea Island types of cotton appeared to be the standard. These were white cottons of good quality, but they appear to have been entirely superseded by the Ashmuni, which was discovered in the early sixties. This was a cream-brown cotton, which very quickly came to be the Egyptian cotton, and so rapidly did the cultivation of this variety increase that by 1870 it was, with the exception of a few small areas still cultivated in the earlier varieties, the only cotton grown in Egypt. At the present time Ashmuni is the cotton of Upper Egypt, occupying a very considerable proportion of the cotton area there.*

Between 1882 and 1885 the Mit Affifi variety was introduced, and this rapidly took the place of Ashmuni in the Delta, and within a few years became the principal variety cultivated in that section. Other varieties have followed in rapid succession, but these have been almost entirely grown in the Delta. It was, however, in the days when Mit Affifi was the variety principally grown in the Delta, with Ashmuni holding almost undisputed sway in Upper Egypt, that the cotton industry of the country made its greatest development and reached its highest level of production.

The period from 1870 to 1897 was one of steady increase in acreage planted to cotton, in the amount of the total crop, and in the average yield per feddan.

In the latter of these years, the average yield per feddan for the whole of Egypt, with an area planted to cotton slightly over 1,000,000 feddans, was 5·80 kantars. At this time 22 per cent. of the total cultivated area of Egypt was planted to cotton.

From 1898 to the present time, the story of the cotton crop in Egypt is slightly different. There have been considerable variations in the acreage planted, in the total crop produced, and most important—a strong decline in the average yield per feddan.

*Upper Egypt is that portion of Egypt lying to the South of the Delta, approximately from Cairo. Geographically it extends to Wadi Halfa. In relation to agriculture, however, Upper Egypt may be taken as including the fertile lands of the Nile Valley from Aswan on the south to the bifurcation of the Nile at the Delta barrage near Cairo. Approximately one-fifth of the cotton area of the country is to be found in Upper Egypt, where the basin system of irrigation still persists to a very considerable extent, although canal irrigation is gradually being provided. Basin irrigation has been entirely superseded in the Delta by the canal or perennial irrigation.

The causes which have operated to bring about this reduction in average yield may be taken under discussion.

The following subjects are of interest in this connexion: (1) The Increased Water-Supply; (2) The Development of New Varieties of Cotton; (3) Insect Pests; (4) Decrease of Farm Animals; (5) Over-cropping.

I. The Increased Water-Supply.

The story of the development of the cotton industry in Egypt is very largely an account of the development of the water-supply. Cotton is a crop which requires a very considerable amount of irrigation over a long period, and, until quite recently, this meant irrigation for the whole year.

Most of the cotton grown in Upper Egypt has been in the past, and continues to be at present, grown under what is known as the basin system of irrigation.

This was the ancient method of irrigation for the whole of Egypt. Under this system the land was divided, by means of high and strong dykes, into sections or basins which were filled with Nile water when the river was at its flood and carrying its load of soil-enriching mud brought from the mountain slopes of Abyssinia. These basins were filled and allowed to stand for some weeks, the sediment in them being deposited on the surface of the land. The water was then drawn off and the crops planted.

The amount of water held in the soil was sufficient to carry the cotton crop through a good part of its growing period, but this needed to be supplemented by further applications in the latter part of the summer. For this purpose it was necessary to have available water. In some places this could be supplied by means of canals, so long as the water in the river was of sufficient height. In other places wells were necessary, from which the water was raised by means of sakhias and shadufs; water was often raised by these means from distributing canals, and even from the main channel of the Nile itself, on to the fields when they were considerably above the water-level.*

One of the first efforts of Mahommed Ali in connexion with the development of his cotton-growing scheme was the establishment of additional sources of water-suppy and the provision of necessary appliances for raising it. He caused wells to be established and sakhias to be provided for which, however, the peasants had to pay.

*The sakhia or Persian waterwheel is mounted over or in the water-supply to be lifted. If the lift is not great, the rim of the wheel may dip into the water below and rise above ground-level. In this case receptacles are attached to the wheel itself, which being submerged during the turn of the wheel, take up their fill of water, and on rising to the highest point of the turn, pour out their contents into a trough, which leads the water into the small distributing canals. When the lift is from a greater depth, a belt arrangement is provided for carrying the receptacles. The wheel is turned by any of the domestic animals working a sweep, which communicates power to the wheel by means of a bevel gear.

The shaduf is an arrangement of bucket and sweep. The bucket is dipped into the water below, lifted and emptied into the canal above. A counterpoise of sun-dried mud is usually provided at the other end of the sweep to help in raising the water.

Later, the Viceroy conceived the idea of a barrage for raising the level of the water at the southern part of the Delta to such an extent as to enable it to be delivered into canals over a greater area than was formerly possible. The development of this idea resulted in the building of the Delta Barrage, which is situated at the bifurcation of the two main branches of the Nile at the apex of the Delta. This allows water to be held up to a head of about 13 feet above the former summer level of the river, and makes it possible to deliver water by gravity to a much wider area than formerly, and has resulted in bringing a very considerable additional area of land under cultivation. But even with the Delta Barrage the summer water was often scarce, because there was no storage reservoir for holding it up in large volume from which it could be delivered as needed, and thus furnish a supply in late summer.

The need for a reservoir to provide storage water resulted in the building of the Aswan Dam, which was completed in 1902. It was found to have an insufficient capacity for the demands made upon it as it was first built, and in consequence, it was considerably increased in height, and an additional head of 5 metres of water was held up and its storage capacity about doubled. The extension was completed in 1912.

The completion of the Aswan Dam resulted in still greater areas of land being brought under cultivation.

The Delta Barrage was first completed in 1861, but its construction was faulty, and it was of practically no value until the completion of extensive repairs in the period between 1887 and 1890.

There seem to be no figures available for the total cultivated area, or the area planted in cotton for the whole of the period from 1890, when the full value of the Delta Barrage began to be felt, and the completion of the Aswan Dam in 1902. Such figures are available, however, from 1891 on to the present time. From comparison of the figures showing the total crop of the country for the years 1890 to 1893 with those for the next few years, it would appear that the acreage under cotton cultivation did not increase very much during that time (1890-1902).

In 1894, cotton occupied an area of just under 1,000,000 feddans. In 1902, this area had increased to about $1\frac{1}{4}$ millions. From 1902 on to 1914, the increase was steady and rapid. The figures given for 1902 are 1,275,677 fedans, and in 1914 the cotton area was 1.755,270 feddans. During this period the proportion of cotton to cultivated land increased greatly.

It may be of interest to note also the figures showing the total area cultivated during this period. In 1894 this amounted to 4,796,250 feddans ; in 1902 it was 5,334,565, and reached its maximum in 1905 when 5,403,891 feddans were under cultivation. In 1906 the cultivated area fell off slightly, and in 1907 it was just short of the record figure of two years earlier. From 1907 the variation in these figures has not been great except for two years, 1914 and 1917, when it was only slightly over 5,000,000 feddans.

The ever increasing importance of the cotton crop has led to a steady increase in the proportion of land devoted to the cultivation of this plant. In 1894, cotton occupied 20 per cent. of the total area. This percentage steadily increased year after year until 1914, when 35 per cent. of the total area was under cotton. This unusually high figure is partly explained by a considerable falling off in the total cultivated area, and an increase in the cotton area, for it was in this year that the cotton area reached its maximum.

Previous to 1897, the average yield per feddan had been steadily increasing. The yield of 2½ kantars in the earlier days, representing the best yields on the best lands, was followed by average yields for the whole crop of 3·30 and 3·46 in 1886 and 1887. In 1894 the average yield was 4·78, and in 1897, 5·80 kantars per feddan. This phenomenal yield has never since been touched, the figures showing a considerable variation from year to year, with a tendency always downwards. Discussion of these figures would seem to reveal the following facts. The improvement of the distribution of the water-supply resulting from the completion of the Dalta Barrage increased the amount of the crop, and the average yield, but does not appear to have increased the total area under cultivation at anything like the same rate. Thus in 1887 the total cultivated area was just under 5,000,000, feddans, and in 1897 it was just over that figure, while the proportion cultivated in cotton had increased only from 20 to 22 per cent. This would indicate that the better distribution of water had resulted in better crops being grown on the same lands, and that very little new land had been brought under cultivation. The effect of the Delta Barrage was felt on the cotton crop of the Delta only. In 1897, the cotton area in Upper Egypt was no more than in 1888, and in these two years it was above the average for the period. It may be assumed that at this time there was no considerable extension of cotton growing in Upper Egypt, and that the figures for the development of the industry during these few years reflect the influence of the Delta Barrage in Lower Egypt.

In the next few years, before the water for the Aswan Dam became available to cultivators, there was a substantial increase in the total cultivated area, and in the proportion planted with cotton, while in the few years immediately following this great work the increase in cultivated area was rapid, and that in the proportion devoted to cotton, even more rapid.

The years 1905-7 include the maximum areas under cultivation in Egpyt, and from that time to the present there has been a fairly substantial decrease with no great variations in area from year to year. During this same period the acreage planted to cotton has increased somewhat, while the ratio between the two has increased in consequence much more rapidly; and this period is that in which the average yield has been declining. The accompanying table gives the figures under these several heads for the period under review.

TABLE I.

Year.	Cultivated area, feddans.	Cotton area, feddans.	Per cent. cotton to total area.	Average yield per feddan, kantars.	Five-year means of average yields, 1894-98 to 1914-18.
1894	4,796,250	965,946	20·1	4·78	...
1895	4,874,456	997,735	20·4	5·27	...
1896	4,942,641	1,050,749	20·2	5 60	...
1897	5,047,698	1,128,151	22 3	5 80	...
1898	5,087,887	1,121,262	22·0	4 98	5·16
1899	5,185,835	1,153,307	22·2	5 64	5·46
1900	5,231,298	1,230,319	23·5	4·42	5·29
1901	5,267,391	1,249,884	23·7	5·10	5·19
1902	5,334,565	1,275,677	23·9	4·58	4·94
1903	5,224,469	1,332,510	25·5	4·88	4·92
1904	5,376,779	1,436,709	26·7	4·39	4 67
1905	5,403,891	1,566,602	28·9	3·80	4·59
1906	5,339,638	1,506,291	28·0	4.61	4·45
1907	5,402,716	1,603,224	29·6	4·51	4·44
1908	5,326,512	1,640,415	30·8	4·12	4·29
1909	5,373,892	1,597,055	29·7	3·13	4·03
1910	5,345,352	1,642,610	30·7	4·57	4·19
1911	5,263,859	1,711,241	32·5	4·31	4·13
1912	5,285,454	1,721,815	32·5	4·35	4·10
1913	5,282,626	1,723,094	32·6	4·45	4·14
1914	5,023,230	1,755,270	34·9	3·67	4 27
1915	5,308,890	1,186,004	22·3	4·05	4·17
1916	5,232,271	1,655,512	31·9	3·06	3·91
1917*	...	1,677,000		3·76	3·80
1918*	...	1,361,000		4·00	3·71

*The figures in this table for the years 1917 and 1918 are taken from *The Times* Trade Supplement, Egyptian Section, February 1919.

If the figures for the average yield are considered in two periods of time, the one from 1894 to 1902, and the other from 1903 to the present time, it will be seen that the influence of the water from the Aswan Dam has been to produce lower average yields.

This reduction in average yields results from the inclusion of considerable areas of new land producing smaller crops, and fr. m a reduction in yield in many sections as a result of the raising of the level of the water in the canals and the consequent rise in subsoil water. This increased water-supply has made it possible to extend the cotton industry and, indeed, cultivation in general, in Egypt, but the increase in irrigation without a corresponding attention to drainage has resulted in reduced yields on some of the older lands in the most fertile parts of the Delta.

The increased water-supply has been more largely available for the perennial irrigation of the Delta than for the basin irrigation of Upper Egypt, although cotton has increased in importance in the latter district. It will, however, be seen by reference to Table III, that, while the area under cotton in Upper

Egypt has increased very considerably, the average yield has been fairly constant with slight variations from year to year.

A certain amount of land in Upper Egypt has been converted in recent years from basin to perennial or canal irrigation, but this has not meant that new land needing reclamation has been taken up, so much as that the land formerly cultivated, which was fertile and producing good crops, has been provided with a more efficient system of water-supply.

The influence of the increased water-supply on the falling rate of yield may be summed up under two heads : (1) increased water-supply has not been accompanied by sufficiently increased drainage, and this has led to smaller yields of cotton in some instances, and (2) increased water-supply has enabled the extension of cotton cultivation to new lands which are of poorer quality than those longer under crops, and the lower yields of these have brought down the general averages.

II. Varieties of Cotton.

Although many varieties of cotton have been grown on a commercial scale in Egypt, only three of these appear to have greatly influenced the average yield of the cotton crop. Ashmuni was the Egyptian cotton from about 1870 until the appearance of Mit Affifi, which was introduced about 1882-85. For several years Mit Affifi steadily increased in importance until, probably in the late eighties, it became the principal variety grown in the Delta, while Ashmuni became the cotton of Upper Egypt, which position it has held up to the present time.

It is probable that Mit Affifi was a heavier yielding variety than Ashmuni, and therefore this change in the varieties grown was associated with the increased average yield during the period 1886-97, the first ten years of the supremacy of the Affifi. Ashmuni has probably not changed nor deteriorated very much in the sixty years it has persisted as an important variety in Egypt, especially in the matter of yield, since the average for Upper Egypt (Ashmuni) is very good, the mean for the last ten years being 4·16 kantars per feddan, as against 4·03 for other varieties in the same period in Lower Egypt. The accompanying Tables II and III give figures for the average yields in Upper and Lower Egypt. The figures for Upper Egypt may be taken as representing approximately the rate of yield of Ashmuni, while those given for Lower Egypt refer to the other varieties grown.

It is worthy of note that Ashmuni in Upper Egypt has continued to be grown on land that has received to a large extent the benefit of deposits of Nile mud brought down in flood and deposited in the basins, while the varieties of Lower Egypt have been grown on land which received water through canals, thus losing most of the Nile mud, which has a very considerable fertilizing value.

Affifi was the predominating variety in the Delta until very recently. In 1906, 77 per cent. of the total crop of Egypt was of this variety. This is equal to about 92 per cent. of the crop of the Delta where most, if not all, of this variety was grown. From 1906 on, the proportion of Affifi in the crop has steadily

grown less and less. This variety was still predominant in 1914 although in that year it constituted only 26·6 per cent. of the total crop, or 32 per cent. of the crop in the Delta.

Sakel was introduced in 1911. In 1914 it amounted to 26 per cent. of the crop of the Delta. In 1916 it provided something like 79·5 per cent., and in 1917 about 86·5 per cent. of the crop of the Delta, and in this latter year it amounted to 67·6 per cent. of the total crop of Egypt. Table IV gives figures to show the proportion of cotton area planted to the principal varieties in each of the twelve years, 1905-16.

The favour which Sakel has found with the planter, does not result from its being a heavy yielding variety, so much as from its finer qualities which have given it a special place in the cotton manufacturing world. At the same time its earliness is greatly in its favour in the face of the advent of the pink boll-worm.

In general it may be said that during the years when the Egyptian Cotton Industry was being developed and established on a firm basis (1860-1900), the adoption of Ashmuni and Affifi as the principal varieties had a considerable influence on the higher average yields obtained, while, more recently, the production of other varieties, which, though possessing desirable qualities, have been less prolific, has helped in the general downward tendency in the average yield per feddan.

Table II.

SHOWING THE INCREASE IN THE COTTON AREA, THE COTTON CROP AND THE YIELD PER FEDDAN IN LOWER EGYPT IN THE YEARS 1896-1916.

Year.	Cotton area, feddans.	Crop, kantars.	Yield per feddan, kantars.
1896	970,000	5,480,000	5·6
1897	1,030,000	6,070,000	5·9
1898	1,030,000	5,240,000	5·1
1899	1,060,000	6,100,000	5·7
1900	1,140,000	5,070,000	4·4
1901	1,140,000	5,940,000	5·2
1902	1,140,000	5,370,000	4·6
1903	1,170,000	5,740,000	4·9
1904	1,190,000	5,200,000	4·3
1905	1,250,000	4,900,000	3·9
1906	1,260,000	5,980,000	4·7
1907	1,290,000	5,840,000	4·5
1908	1,299,000	5,500,000	4·2
1909	1,330,000	3,908,000	2·9
1910	1,320,000	6,049,000	4·6
1911	1,350,000	5,906,000	4·4
1912	1,350,000	5,923,000	4·4
1913	1,340,000	6,296,000	4·7
1914	1,370,000	5,061,000	3·7
1915	930,000	3,748,000	4·0
1916	1,290,000	3,779,000	2·9

Table III.

SHOWING THE INCREASE IN THE COTTON AREA, THE COTTON CROP AND THE YIELD PER FEDDAN IN UPPER EGYPT IN THE YEARS 1896-1916.

Year.	Cotton area, feddans.	Crop kantars.	Average yield per feddan, kantars.
1896	80,000	400,000	5·0
1897	100,000	270,000	4·7
1898	90,000	350,000	3·9
1899	90,000	410,000	4·5
1900	90,000	370,000	4·1
1901	110,000	430,000	3·1
1902	110,000	470,000	4·3
1903	160,000	770,000	4·8
1904	240,000	1,110,000	4·6
1905	310,000	1,000,000	3·2
1906	250,000	970,000	3·9
1907	310,000	1.390,000	4·5
1908	340,000	1,250,000	3·1
1909	270,000	1.092,000	4 0
1910	320,000	1,152,000	4·7
1911	360,000	1,518,000	4·2
1912	370,000	1,802,000	4·8
1913	350,000	1,725,000	4·5
1914	380,000	1,490,000	3·9
1915	250,000	1,090,000	4·4
1916	360,000	1,280,784	3·5

Diagram showing the average yields of cotton in kantars per feddan in Upper and Lower Egypt. Smoothed curves, five-year means of averages 1896-1900 to 1912-16.

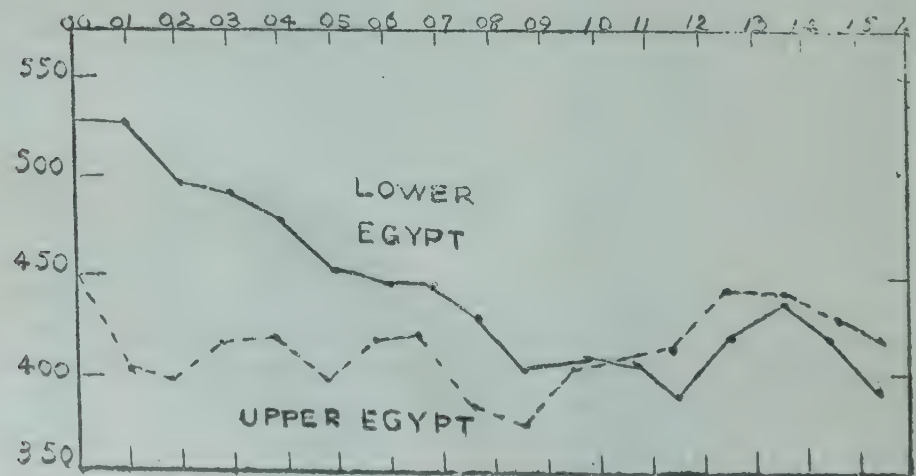


TABLE IV.

SHOWING THE TOTAL COTTON AREA AND THE PRCENTAGES PLANTED TO EACH OF THE FOUR PRINCIPAL VARIETIES IN THE YEARS 1905-16.

Seasons.	Cotton area, feddans	MitAfifi, per cent.	Jannovitch, per cent.	Sakel, per cent.	Ashmuni, per cent.
1905	1,566,602	73·7	4·6	...	18·8
1906	1,506,291	77·3	5·6	...	14·9
1907	1,603,224	66·6	9·7	...	18·7
1908	1,640,415	59·9	14·5	...	19·7
1909	1,590,555	65 9	12·4	...	15.8
1910	1,642,610	61·6	12·7	...	17·7
1911	1,711,241	49·4	14·7	7·9	19·3
1912	1,721,815	40·2	13·9	11·5	20·0
1913	1,723,094	36·2	10·0	14·4	20·7
1914	1,755,270	26·6	7·3	22·4	20·2
1915	1,186,004	17·7	2·4	46·2	19·6
1916	1,655,512	8·5	0·3	62·3	28.0
1917*	1,677,000	5·7	0·1	67·6	21·6
1918*	1,316,000	2·7	0·1	72·4	20·8

III. INSECT PESTS.

The principal insect pests of cotton in Egypt are as follows :—

Cotton worm	(*Prodenia litura*)
Boll worm	(*Earias insulana*)
Cotton stainer	(*Oxycarenus hyalinipennis*)
Pink bollworm	(*Gelechia gossypiella*)

These are all of different species from the cotton pests of the West Indies, although it will be noticed that three of them have the same common names as the West Indian species which attack cotton in the same way. The boll worm and the cotton stainer appear to have been known in Egypt as pests of cotton since about 1860, and the cotton worm since 1879 ; the pink bollworm is of recent introduction, having been first discovered in 1910.

There is no doubt that any insect which lives in considerable numbers on a crop plant affects its productiveness, either by lowering its vitality or by directly injuring that portion of the plant which is developed as the crop product.

Foaden writing in 1910 states that 'the boll worm is the most important enemy with which cotton growers have to con-

*Figures for 1917 and 1918 taken from *The Times* Trade Supplement, Egyptian Section, February 1919.

tend; it is a much more serious enemy than the leaf eating cotton worm, which only causes serious loss at intervals, and, moreover, can be easily controlled. Furthermore, up to the present no simple and satisfactory means have been found for checking the boll worm wholesale when it has once invaded a field of cotton.'

In regard to the cotton worm the same author states, 'This insect is the second in importance of the cotton pests. The total loss suffered by the country from the ravages of this pest, which defoliates the plants, has been very great, since in certain bad cotton worm years the damage to crop has been assessed in millions of pounds. At the same time it must be remembered that such serious outbreaks as these are fortunately rare, and taking the average year the loss in comparison with the above estimate would be inconsiderable.'

The cotton stainer does not appear to be considered as a serious pest, and no definite steps have been taken to control it.

As far as the effect on the average yield of cotton is concerned, the boll worms and cotton worm seem to be the only insects pests to consider, except for the past few years when the pink bollworm has undoubtedly played its part.

The development of the cotton industry through the periods of low and medium yields to the maximum in 1897 took place in the presence of these two insects—and it is hardly to be argued that, as their attacks did not prevent the gradual rise in the average yields, they have had any considerable influence in reducing them in the more recent period.

The opinion seems general that both these insects are sufficiently abundant in certain years seriously to affect the crops, and the year 1905 might be quoted, when it is reported that both these species were abundant, the water-supply average and the crop was very short, the total being under 6,000,000 kantars and the average 3·80 kantars per feddan. Again, in 1909 the crop was only 5,000,000 kantars, with an average of 3·13 kantars per feddan. This was a bad 'cotton worm' year with very good summer water-supply.

This extremely small crop and average yield in 1909 cannot, however, be attributed wholly, or even largely, to the cotton worm, for in spite of severe attacks of this insect a good crop was developed and nearly ready for picking, when the very high and early flood of the Nile caused tremendous losses. The soil became saturated with water by flooding and by infiltration, and wholesale boll shedding took place and reduced the crop enormously.

The cotton bug or cotton stainer (*Oxycarenus hyalinipennis*) appears to have been known in Egypt since about 1860, that is, for the same length of time that the Earias boll worm has been known. No record seems to exist as to the exact nature and the extent of the injury caused by this insect to the cotton plant. It is a well known fact that the cotton bug occurs in great numbers on the cotton plants in every season, and it is generally believed that it causes some injury and some loss in the cotton crop.

For a number of years past the law requiring the eggs of the cotton worm moth to be collected has been enforced, and it has probably greatly reduced the attacks of the insect, but, in spite of this, the average yield has steadily become smaller.

The figures are not available for any statement as to the amount of the damage done by these pests year after year, but it seems safe to assume that they have had nothing to do with the general falling off in yield per feddan for the past twenty years, since they did not prevent the gradual and steady increase in yield in the period of thirty to forty years from about 1860 onwards. Moreover, as there is no reason to believe that the attacks of these insects have been any more serious in the last twenty years than they were previous to that time.

The influence of the pink bollworm has probably been in the direction of smaller yields since it became established as a pest, but this affects only the past few years, from 1912 on, and has no bearing on the general subject under consideration, that is, the steady falling off in yield for the past twenty years.

IV. Decrease in Farm Animals.

In most agricultural countries, especially those in which an intensive form of agriculture is practised, the number of farm animals has a direct bearing on the fertility of the soil. In Egypt the source of fertility in the soil has been for centuries past the muddy sediment from the Nile water, and it would seem likely that, so long as all the agricultural lands were irrigated by the basin system, very little attention was paid to fertilizing materials other than that which was supplied by means of the annual flood.

With the extension of the canal system, or rather with the reduction of the basin system of irrigation, the land has suffered from the loss of the annual deposits of the Nile mud. Any system of enriching the land with farmyard manures has suffered in recent years by the very considerable decrease in the numbers of farm animals in Egypt, and at the same time there has been a very substantial increase in the population of the country. The decrease in the number of farm animals means a decreased amount of animal excrement, while the increase in the population makes much greater demands on this as a source of fuel. This combination of circumstances decreases tremendously the amonnt of organic manure available for application to the land.

The fellah has learned that some form of manuring is necessary, and his system of agriculture provides a certain amount of green manures. Other manures are ordinary farm manure, pigeon guano, and coufri This latter is earth impregnated with nitrates and other manurial material from the sites of ancient villages. In certain localities in Upper Egypt native rock deposits occur, which contain considerable proportion of nitrates and phosphates which are used in some districts rather extensively. In the past few years the use of commercial fertilizers has been extended, the imports showing an increase from 2,000 tons in 1902 to a maximum of 72,900 tons in 1914.

In Egypt, the use of green manures is not according to the system practised in many countries where these crops are grown purely for the purpose of being turned into the soil for soil improvement. The Egyptian system of agriculture includes a long list of leguminous plants. These are usually intended to yield a crop, either as in the case of the Egyptian clover which fields several cuttings of green fodder, or as in the case of peas, beans, ground nuts, etc., which yield a crop of fruit. The clover yields furnish grazing for the peasants' domestic animals during the clover season, and the peas and other similar crops furnish in their vines and leaves a certain amount of fodder. When the manure from these animals is returned to the land, the manurial value of these plants is available for soil improvement, and a large portion of their root systems as well as fallen leaves and bits of stem remain in the soil to its advantage.

The demand for fuel, however, is so great that much of the manure, the bulk of the stems, stalks and leaves of plants that are not useful for stock food are burnt, and it is not an uncommon sight to see the children of the peasants collecting the roots of all sorts of plants for fuel.

The increase in the population then, has resulted in much material being used for fuel which ought to find its way back into the land for improving its fertility. Much of this fuel is the manure of domestic animals, and in addition to this the numbers of such animals in Egypt has greatly decreased in recent years.

TABLE V.

SHOWING THE DECREASE IN THE NUMBER OF BOVINES AND BUFFALOES IN EGYPT FROM 1903 TO 1914.

Year.	Cattle.	Buffaloes.	Total.
1903	859,669	718,023	1,677,692
1904	605,022	645,796	1,250,818
1905	655,156	708,233	1,363,389
1906	732,537	775,149	1,507,686
1907	778,896	761,486	1,540,382
1908	737,732	750,548	1,488,280
1909	725,116	728,284	1,553,400
1910	762,091	765,392	1,527,483
1911	656,166	657,406	1,313,572
1912	619,540	652,186	1,271,626
1913	637,098	632,725	1,269,823
1914	601,136	568,388	1,169,524

V. OVERCROPPING.

The general opinion in Egypt with regard to the proportion of the total cultivated land which may safely be grown under cotton is that this should be something like one-third the total on any estate or holding. To grow a larger proportion than this seems to be considered bad agricultural practice.

The figures presented in Table I show that, in 1894, 20 per cent. of the total culivated area was in cotton, and that

in the years 1911-14 it stood at over 30 per cent., reaching 35 per cent. in 1914. These figures, however, represent a relation between the total cultivated area and the area planted in cotton, and not between the total area suitable to cotton, which might be spoken of as cotton land ,and the area planted in that crop. The following table gives figures to show the relation between cultivated areas and areas planted in cotton in the different provinces in Egypt, from which it will be seen that in one province at least, practically 50 per cent. of the land was devoted to cotton cultivation in 1916, while all the provinces in Lower Egypt had more than one-third of the total area under this crop in that year.

During the period of highest average yields of cotton in Egypt (1894-1903) the percentage of cotton area to the whole cultivated area was 25 per cent. or less, and during the years of smaller average yields, the percentage figures have grown larger.

Cotton is believed by many in Egypt to be an exhausting crop, and the idea seems to prevail that overcropping or growing more than one-third of the land in cotton on any estate or holding takes something out of the land, or does something to it which automatically and of necessity renders the land less fertile and less able to produce cotton.

Table VI.

SHOWING THE PERCENTAGE OF TOTAL CULTIVATED AREA PLANTED TO COTTON IN 1916, IN THE SEVERAL PROVINCES OF EGYPT.

Province.	Cultivated area, feddans.	Cotton area, feddans.	Percentage in cotton.
In the Delta.			
Dakahlia	480,180	238,970	49·77
Gharbia	892,804	414,241	46·40
Beheria	581,498	240,874	41·40
Charkia	519,891	212,189	40·81
Menufia	345,187	118,454	34·32
Qaliubia	192,285	65,141	33·88
In Upper Egypt.			
Beni Suef	222,330	72,892	32 78
Minia	376,690	122,743	32·58
Fayoum	299,470	80,058	26·73
Giza	176,121	32,739	18·80
Assiout	414,427	50,818	12·13
Girga	310 835	3,392	1·09
Aswan	79,376	708	0·87
Qena	342,033	2,293	0·67

It is probable that the effect of cultivating the larger proportions, as has been the practice in recent years, has not been to produce exhaustion of the soil, but that the loss of fertility has come about by the use of too much water. In former days in the Delta especially, when all water for irrigation had to be raised by labour, either of the cultivators or of their animals, irrigation was expensive, and there was little likelihood of too much water being applied. More recently, with high level canals and an abundance of water, it is probable that many farmers have used too much water on their cotton fields, and that when cotton has occupied the same land too frequently, the effect of continued overwatering has had a tendency to reduce the amount of the crop.

GENERAL CONCLUSIONS.

The average yield in Egypt of cotton per feddan has been getting smaller steadily for the past twenty years. Increased water-supply by irrigation has encouraged the planting of cotton on large areas of new lands of poorer quality, which have produced small yields; and an increased water supply without adequate drainage has resulted in reduced yields in some of the best cotton districts.

The decrease in the number of farm animals which has taken place simultaneously with an increase in the population has reduced the amount of farm manure available for the land. This has tended to lower the average yields of the total cultivated area.

Insect pests do not appear to have had any influence in reducing the average yields of cotton, except, that, from 1912 and 1913 the pink bollworm has been a pest which has undoubtedly caused serious losses.

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PART II.

THE PINK BOLLWORM.

Native Home and Distribution.

The pink bollworm is a native of Asia, and was first recorded in 1842, when specimens were sent from India to England for identification. The insect was described as a new species by W. W. Saunders, an eminent entomologist of that time, and his description was the first published record concerning it For over sixty years nothing further seems to have been published in regard to this insect. In 1904, it was reported from German East Africa, in 1909, from Hawaii, and in 1910 it was discovered in Egypt.

The insect was introduced into Hawaii and Egypt from India, and it is probable that the infestation in German East Africa came from the same source. More recently it has made its appearance in Brazil and Mexico, into both of which countries it was introduced from Egypt. It has made its appearance at certain points in Texas, having found its way into that State from Mexico.

The pink bollworm is very generally distributed throughout the Asiatic district. It was first recorded from India, probably because it was in that place that early attempts were made to improve the cotton industry. When new varieties of cotton were imported and grown in India they were seriously attacked by the pink bollworm. This might be due to the fact that these imported varieties, being of special interest, were kept under more careful observation than the native varieties. It would, however, seem more likely, that the imported varieties were more seriously attacked than the native, and that the relation which existed between the pink bollworm and the native varieties in India was that which ordinarily exists between a plant not far removed from its wild condition and an insect indigenous to the country and adapted to that particular plant.

Indian cotton was not a highly specialised plant. It had not then been much developed by selection and cultivation, away from its wild condition, and even at the present time certain cultivated varieties in India are very little different from wild plants of the species they represent.

It is well known that where a definite relation exists between an insect and its food plant, especially where the insect confines itself to one species of food-plant, or to a very narrow range, the insect does not do great damage to the plant, or develop in enormous numbers. The introduction of another species or variety of plant, acceptable to the insect as food, results usually in much more serious attacks. In a similar manner the introduction of an insect into a new locality often enables that insect to become a serious pest, even though in its original home it may have occurred in very small numbers.

It is quite likely that if these early trials with introduced cotton had been made in any of the other Asiatic localities where the pink bollworm is now known to exist, this insect would have been found there attacking the introduced varieties.

In the East, this insect occurrs in India, Ceylon, Burma, Bengal, China, Straits Settlements, and the Philippines, and it may be a native species throughout the whole of this range. It has also been recorded as occurring in Japan, but this record seems to need verification.

On the continent of Africa it occurs in Egypt, Soudan, Nigeria, Zanzibar, Sierra Leone, East Africa and West Africa. It may fairly be supposed that all these African occurrences may have resulted by direct introduction, from the East, or by distribution from one or another of these localities after being brought there from the East.

This introduction may have resulted through the Indian labourers who have from time to time gone to the African colonies, carrying with them seeds for planting cotton containing infested seeds in their bedding and other personal effects.

As already stated, the pink bollworm was introduced into Hawaii from India about 1909. Its occurrence in Hawaii was recorded by D. T. Fullaway, Government Entomologist. (9)

The introduction into Egypt was effected by means of badly ginned cotton containing infested seeds. During the period 1903-13, considerable quantities of Indian cotton were imported into Egypt. The largest figures for such importations are given for 1906 and 1907, when the amounts were 81,240 kilos and 162,000 kilos, respectively. The pink bollworm was first discovered in Egypt in 1910. The introduction into those American localities where the pest is now known, resulted from the importation into Brazil and Mexico of seed for planting from Egypt.

An account of the introduction of the pink bollworm into Brazil is given by W. D. Hunter * who refers to a statement on the subject by Mr. Edward C. Green, Superintendent of the Cotton Department, Ministry of Agriculture, Brazil. According to this authority, careful inspection throughout the greater portion of the cotton-producing area in Brazil was made in 1913, and no infestation of pink bollworm was found. In 1916, however, another similar inspection revealed the presence of this insect over wide areas in the United States of Parahyba, Rio Grande del Norte, and Ceara.

It appears that in the years 1911, 1912, and 1913, the Government of Brazil imported Egyptian cotton seed to the extent of 9 tons. This seed was not fumigated, and it is almost

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* 'The Pink Bollworm with special reference to steps taken by the Department of Agriculture to Prevent its Establishment in the United States.' By W. D. Hunter, in Charge of Southern Field Crop Insect Investigations, and Member of the Federal Horticultural Board. *Bulletin 723*, August 30, 1918.

This Bulletin was issued after the period covered by the work of the present writer in Egypt. References to the occurrence of the pink bollworm in Brazil, Mexico, and Texas are from this Bulletin.

certain that it was the means of introducing the pink bollworm. Egyptian cotton seed in 1912 and 1913 would certainly have contained a sufficient amount of pink bollworm to provide for its introduction.

The occurrence of pink bollworm in Mexico resulted from the introduction of large quantites of Egytian seed for planting in 1911. According to Hunter, there were two importations, one of 125 sacks, and the other of 6 tons of seed. The pink bollworm was sufficiently abundant in Egypt in 1911 so that this quantity of seed would be certain to contain insects enough to establish the pest in a new locality.

The occurrence of the insect in Texas, results from the transportation of cotton seed from Mexico to certain oil mills in Texas when the oil was extracted from the seed. One limited area of infestation came about from bales of ginned cotton which had been taken to Galveston for transhipment. While this cotton was on the wharves of this port, the serious storm of August 1915 swept many of them away. Some of the bales were washed ashore, and it is assumed that the moths escaping from seeds in this cotton infested the adjoining cotton fields.

Most energetic measures have been taken by the United States authorities to eradicate the pink bollworm from those districts in Texas to which it had gained admission, and there seems, according to reports received, a very fair prospect that this work will be successful. In all other localities where this pest occurs, there would seem to be no possibility that it will ever be eradicated, and cotton growers in those countries must face a future in which the pink bollworm has to be taken into account in the production of cotton.*

It is a matter of record that on several occasions parcels of infested cotton seed from Egypt have been carried by post into the United States, and it is only due to careful quarantine regulations that the pink bollworm was not introduced in this way. In 1916, the steamship Appam arrived at Newport News, Virginia, as a German prize of war, having on board some 4,000 bags of infested cotton seed from Lagos, West Africa. This seed was dealt with by the Federal Horticultural Board and converted into fertilizer by treatment with sulphuric acid. Fumigation of the holds of the Appam in which the seed had been contained with a heavy dose of cyanide, together with thorough cleaning up of scattered seeds wherever the seed was handled were the additional precautionary measures adopted. The nearest cotton fields which were about 10 miles distant, were repeatedly inspected for the purpose of ascertaining if any infestation had come about as the result of the escape of moths from this seed. No such infestation has been found, and it is believed that the measures adopted were satisfactory.

In November 1918, a schooner arrived at Barbados with a mixed cargo from Para. The cargo included a quantity of

* The information as to the investigation of pink bollworm in Texas became available since the preparation of the report under review, but has been added to the present paper on account of its general interest.

cotton seed for Barbados, and cassava and cassava farine to be landed at Barb dos awaiting transhipment to Englsnd. This cotton seed was infested with pink bollworm, and on this account not only the cotton seed, but the entire cargo was refused admission to the isl nd because of the danger of introducing the pest.

These instances are cited to show the means by which pink bollworm may be introduced, and to emphasize the necessity of proper quarantine regulations against this most troublesome insect.

The pink bollworm is probably the most cosmopolitan of all the important cotton pests, and in those countries where it is established its effects on the cotton industry are as serious as those of any pest in any country.

Description of the Insect.

The pink bollworm was first described by Saunders in 1842 as *Depressaria gossypiella*. It was afterwards referred to the genus *Gelechia*, and more recently, Busck (36) in 1917, refers it to a new genus, *Pectinophora*, which he erects to contain this and one other species.

Fig. 1.—The pink bollworm (*Pectinophora gossypiella*): Adult. Much enlarged. (Busck.) (*U. S. Dept. Agric; Bull.* 723).

The general appearance of the freshy emerged and unrubbed n oth is that of a metallic coppery brown, with blackish spots, or areas which vary in size and intensity. The apex of the fore wings is blackish ; this is separated from a median, blackish area by a paler band. The outer margin of the fore wing is bordered with a fringe of delicate hair-like scales. The hind wings are silvery grey in colour, and are provided with a dense fringe of long, fine hair, like scales, of the same colour as the rest of the

wings. The head and palpi are of the same general colour as the wings. A moth which has flown about and become rubbed is first denuded of scales on and about the head, and the wings lose most of their black scales and consequently the characteristic colour patterns.

The body of the moth is rather stout, especially in the female. The abdomen is pale and somewhat the colour of the hind wings, but without the silvery effect. The extremity of the abdomen is provided with a tuft of scales.

The male and female moths are much alike in appearance. The male is usually slightly the smaller, with a less robust body. The distinctive characteristics are the tubular ovipositor of the female and the pair of flat, scale-like claspers of the male. These may be observed in freshy killed specimens by applying slight pressure to the abdomen, which causes the ovipositor to protrude and the claspers to separate.

The length of the body of the moth is about 10 mm., and the wing expanse ranges from about 15 mm. to 20 mm.

The egg of the pink bollworm is very small and inconspicuous, measuring about 0·5 mm. in length by 0·25 mm. in diameter, slightly irregular in form, the general outline being oval, slightly more pointed at one end than at the other. When first laid the eggs are of a pearly white to faintly greenish colour. They are very difficult to detect without the aid of a lens. They are laid singly or in small groups. Busck (loc. cit.) states that according to his observations, the eggs are deposited, in Hawaii, on any part of the green cotton boll, or its calyx, or even in the flower, but are by far most commonly found near the apex of the green boll in the slight longitudinal depressions which indicate its divisions.

Willcocks (32) states that the eggs may be found on almost any part of the cotton plant including the bolls, squares, braceoles and leaves, both the young and old leaves, in the axils of leaves and buds, and also on the small leaves of the growing points.

The present writer states (Report, Egyptian Government in MSS.) the moth deposits eggs on the green parts of the cotton plant, leaves, buds, bolls, bracts, etc. They are generally laid singly, scattered about over the plant, though groups of from eight to ten are to be found.

The female moth is capable of producing a large number of eggs. Willcocks estimates this number at 250 for a small individual, and as high as 500 for a large, well developed moth under natural conditions. Busck states that the number of eggs laid by a single female is difficult to ascertain in nature, but dissections prove that each female is capable of laying more than 100 eggs.

The eggs are, as a matter of course, also deposited on the other food-plants in which the larvae live. In Egypt these are Bamia (*Hibiscus esculentus*). Teel (*Hibiscus cannabinus*), and Hollyhock (*Althea rosea*). In Hawaii, Busck found the pink bollworm only on the cultivated and other species of cottons.

When first hatched, the larva is less than 1 mm. in length In colour it is slightly yellowish, the comparatively large head

being dark brown, or almost black, and polished. The thoracic shield is rather indistinct, pale, shiny and faintly shaded on the posterior margin.

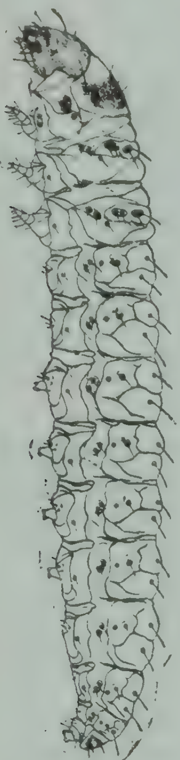

Fig. 2.—The pink bollworm: Outline drawing of larva, showing structure, Much enlarged, (Busck.) (*U. S. Dept. Agric. Bull.* 723)

The pink colouration begins to appear in the larva when it has reached a length of about 6 mm. As growth proceeds, the pinkish colouring becomes more pronounced until the appearance of the full-grown larva is attained. When full-grown the pink bollworm is is some 10-12 mm. in length, the width being about 2·5 m.m. The pinkish colour is due to bands of pigment in each section which are distinct in the earlier stages but, as the larva increases in size and age, these bands spread until the entire surface of the body of the caterpillar becomes suffused with it.

The pupa is a shiny yellowish-brown in colour, about 8 mm. in length, and rather less than 2·75 mm. in width. The surface is covered with a fine pubescence of short tawny hairs. The pupa is enclosed in a silken cocoon consisting of a loosely woven layer of brownish silk.

Life History and Habits.

The pink bollworm moth lives but a short time, probably not more than three to four weeks, although it is not known how long this period may be under natural conditions. Egg-laying commences about the third or fourth night after emergence, and when this is finished the moths die. There is no evidence that this insect is able to live for any length of time in the moth condition waiting for suitable opportunities to deposit the eggs.

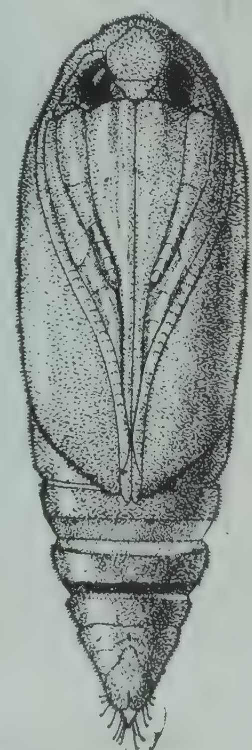

Fig. 3.—The pink bollworm: Pupa much enlarged. (Busck.) (*U. S. Dept. Agric. Bulletin* 723).

The eggs require from four to twelve days to hatch, according to temperature. The larval condition lasts for some twelve to fourteen days in the hot season. This length of time varies somewhat, and there is a distinct phase of the pink bollworm larva which is known as the resting stage, which lasts for a very long time. The pupa occupies a period of some ten days, and there is a short pre-pupal condition which includes the time occupied by the larva in spinning its cocoon. As a rule, in summer, the full life cycle occupies from thirty to forty days, in the case of those individuals

which proceed directly from one stage of development to the next. This length of time is very much increased in the case of those individuals, the larvae of which pass through the resting stage. This will be discussed at another point.

The pink bollworm moth hides during the day, and it is very difficult, almost impossible, to discover any of these insects in the cotton fields by day even though they are present in enormous numbers. They hide under leaves, weeds, stones and lumps of earth, and in cracks in the soil, and they are not induced to take flight by being disturbed.

In seed stores, the moths have been found hiding amongst the seeds, and under planks, sacks, etc., and when disturbed in these situations they make immediate attempts to hide, running or walking rapidly with a quick nervous motion. When disturbed into flight in the seed stores they usually fly only a short distance, 2 or 3 feet, and then drop to the floor or the surface of the pile of seed, and at once scurry to cover.

The moths are attracted to light, and Willcocks found that they were also attracted to sweet fermented substances such as a mixture of beer and molasses. Busck found in Hawaii that the pink bollworm was not attracted to light.

Willcocks ([35]) carried out extensive light trap experiments in the field in Egypt, and captured many thousands of moths. The present writer used light traps for capturing the moths in large breeding cages, and light traps in a cotton-seed store were used for the capture of large numbers of these moths. The attraction of these moths to light will be further discussed at another point.

Fig. 4—Pink bollworm on carpel of cotton boll which shows also typical hole made by worm while travelling from one lock to the next. (*U. S. Dept. Agric., Bulletin 723*).

The pink bollworm larva is entirely an inside feeder. When the eggs hatch the young larva makes its way as soon as possible to the interior of the boll. Practically all the food of the larva is found in the seed in the cotton boll. Probably the larva eats a certain amount of the tissue through which it tunnels in making its way into the boll, and perhaps on leaving one seed for another, or in penetrating the partition in the boll in moving from one locule to another, as sometimes happens, a certain amount of these tissues may be eaten. The preferred food, however, is the interior of the seeds, and this forms the bulk of the food of this insect.

As the interior of the seed is the feeding place of these caterpillars, it is also the place where they live, and the larva of the pink bollworm is not often to be seen in any other situation until it leaves for the purpose of pupating.

In Egypt, the usual practice is to bag the seed as it comes from the gins in ardeb (about 4½ bushels) sacks, and these sacks are stacked in the sheds or yards. During the early part of the ginning season, enormous numbers of pink bollworms leave the seeds, make their way to the outside of the sack, and in the great stacks of these sacks of seed the crawling larvae, and the pupae in their frail cocoons may be found. They are particularly abundant in the angles formed by the surfaces of contiguous sacks.

Pink bollworm larvae have been found feeding in young tender shoots of the cotton plant. This is regarded, however, as an unusual occurrence. They are of course found in the seeds and fruit of other food-plants.

The Resting Stage Larvae.

Pink bollworms may be considered as being of two sorts, one of which passes through its successive stages of development in a direct manner. The other includes an extra period of time known as the resting stage. Larvae which pass through this phase are spoken of as resting stage larvae, while for the others the term short cycle larvae would seem to be app opriate. These latter, on becoming full fed, proceed at once to pupate. The pupa develops and the moth emerges in the course of a few days or a few weeks, according to season.

When the resting stage is to be entered into, the larva, on becoming fully fed, forms a special cocoon and enters into its dormant or resting condition.

This ability to enter this resting stage is the most important characteristic of the pink bollworm in connexion with its control and its dispersion from place to place, as well as being a special phase of particular interest in the life-history of the insect. There seems to be no difference in appearance between the short cycle larvae and those which are going to enter the resting stage, and it is not known what influences act on certain individuals to cause them to make such a great change from what would seem to be the normal life process.

Many insects have the power of assuming a dormant condition for hibernation, and others have similarly the ability to pass through unfavourable hot or dry periods ; but this resting stage of the pink bollworm, while probably a hibernating condition, is much more than that, since larvae not only pass the winter, but according to present knowledge they are able to go through at least two winters and the intervening summer in this condition, and when the insect has been longer under observation it may be found to have a much longer resting stage than that, even.

Willcocks collected large numbers of bolls at the end of the 1913 crop, and moths issued from these during the summer

of 1914 and until August 1915—a period of twenty-two months after the bolls were collected in the fields. Records in the Ministry of Agriculture at Cairo show that moths have emerged from cotton seed thirty-one months after this came from the gins.

During the cotton-growing season the pink bollworm passes through several generations, each occupying some four to five weeks. Toward the end of the season certain larvae acquire the ability to enter into the special condition for the resting stage. This ability to enter the resting stage is the charac eristic in the life-history of the pink bollworm which makes it a most easily distributed pest, and adds to the difficulty of its control. It is, however, the one period in its life-history where control measures may be most easily applied.

In Egypt, the short cycle larvae in the seeds and bolls at the end of the season have no bearing on the infestation of the crop in the next season if there are no food-plants of the insect growing during the winter.

Once the larvae leaves the seed or boll to pupate, the completion of its development is only a matter of a short time, a few weeks at most in winter, and a few days in the hot weather. The moths live only a short time, the females deposit their eggs, and if the young caterpillars find no suitable food, they die. Resting stage larvae in the bolls on the plants scattered on the ground and in the cotton seed are the larvae from which the moths are to be developed for the infestation of the coming crop.

The introduction of the pink bollworm from the East into the various localities where it occurs in Africa, and from Egypt into Mexico and Brazil appears without doubt to have resulted from the transportation of resting stage larvae.

At the end of the cotton season a very large proportion of the pink bollworms immediately pupate, and the moths emerge within a short time. A smaller proportion of the larvae enter the resting stage. So far as can be seen, there is nothing in the conditions of temperature or moisture which could influence a portion of the insects to adopt a condition so much different from that adopted by the great majority. The resting stage larvae spin a very tough cocoon within a cotton seed or within a double seed. This double seed is produced by two seeds being webbed together very strongly by silk spun by the larva. The larva usually rests in a curved position, and in this repect differs from the pupating larva which lies straight. The cocoon of the pupating larva is quite different from that of the restin larva, being more loosely spun.

The union between the seeds in the double seeds is so firm as to afford a very considerable protection to the enclosed insect from the effects of water and its natural enemies,

The seed in which the resting stage is passed is the seeds in which the larva has been feeding, the interior generally being entirely eaten out. The double seeds are a characteristic of the presence of pink bollworm, and provide an easy means of determining infestation in cotton seed by this insect in most cases.

NATURE OF THE DAMAGE CAUSED BY PINK BOLLWORM.

The attacks of the pink bollworm cause losses in the amount and the quality of the crop. The yield is reduced, and the quality of both lint and seed is affected.

The principal loss results from the feeding of the larva. This feeding is almost entirely confined to the contents of the seed. Flower-buds and very young bolls are sometimes attacked and completely destroyed, but the amount of loss from this cause is comparatively small.

The young, newly hatched larva penetrates into the boll tunnels into a seed and devours its contents, and perhaps also the contents of a second or third seed. The number of seeds required to furnish a sufficient amount of food for the development of one larva will depend on the age of the boll when the larva enters it. If the seeds are very small, that is, if the boll is very young, one larva will probably destroy the whole interior of the boll. If the seeds are rather well developed, one or two will provide sufficient food for a larva. If attacked while still very young, the seed may not produce any lint, but if attacked at a later stage the seed may produce a large amount, and it may be attacked even after having produced all its lint.

As to the effect on the seeds, they may be entirely destroyed, or injured in varying degrees. Sometimes the injury is practically nil, sometimes it amounts to complete destruction, while all degrees of injury between these two extremes are found.

In addition to the actual damage done to the lint and seed of the attacked seed, there is the injury which results to sound seed in attacked bolls. This appears to be a matter of malnutrition, the attacked seed making demands on the supply of plant food to such an extent that nearly all the seeds in the boll are deprived of a portion of their nutriment. The germination of such seeds is affected, and they lose in value for planting purposes.

The injury to the seeds appears also to affect the quality of the oil extracted from them. Willcocks gives the analysis of samples of cotton seed, which indicates that not only is the amount of oil reduced, but that in some instances the quality is inferior as a result of pink bollworm attack. Gough (27) summarized the nature of the damage done by pink bollworm as being :—

(1) Reduction in number, weight, and vitality of seeds.
(2) Reduction of weight and quality of lint.
(3) Reduction of percentage of lint (ginning output) with a fall in the quality of the seed, and place of seeds being taken by worthless hulls and broken seeds.

Willcocks states that larvae and pupae may be caught in the gins and crushed, thus staining the lint and affecting its value. The injury from this source would appear to be but slight.

Busck says that the larva eats the seeds, and tunnels and soils the lint, causing the arrest of the growth, and the rotting or premature and imperfect opening of the boll. Not only the seed

and lint actually attacked are lost, but the uninfested parts of the boll are retarded in growth, and greatly depreciated in value by the attack of even a single larva ; when, as is often the case, two, three, or more larvae infest a single boll the valne of the seeds and lint is entirely destroyed. Willcocks gives a record of injury to the stem of the cotton plant in July 1915 by the pink boll-worm. Young cotton plants which had snapped off about 6 inches above the ground were found to have been girdled by the pink bollworm. This form of injury appears to be comparatively rare.

THE AMOUNT OF LOSS DUE TO PINK BOLLWORM.

It has already been shown in this paper that, beginning with the year 1820, the cotton industry in Egypt went through a period of development during which a knowledge of cotton agriculture had to be acquired, new varieties were developed, and, in short, a cotton industry built up from its very beginning.

At the end of a period of about eighty years the industry had reached a most remarkable position. Over a million acres of land were cultivated in this crop, and the average yield had reached the very high figure of nearly 600 ℔. of lint per acre. From that time(1897) to the present, the rate of yield has steadily declined. There have been variations in the amount of yield each drop being followed by a rise, but in every case this rise has failed to reach the temporary maximum which immediately preceded it. This is shown clearly in the figures for the average yield per feddan given in Table I.

The tendency to lower average yields has persisted over a period of about twenty years, the yield for 1897 being the maximum for the whole of the history of the cotton industry in Egypt, and that for 1916 the minimum.

The causes which have operated to bring about and maintain this downward tendency have been discussed in the earlier pages of this paper. It was there shown that this falling off in yield was not due to the action of insect pests, for with the exception of the pink bollworm all the itsect pests of cotton now known to exist in Egypt were present and attacking this crop during the years when the yield per feddan was steadily rising, and the attacks of these pests were probably as severe, and of as regular occurrence then as they have been in the later years when the yield has been decreasing.

The pink bollworm was first discovered in Egypt in 1910. It became a serious pest of cotton in the Delta in 1912, and later spread into Upper Egypt, and infested the entire cotton-growing area. Previous to the advent of the pink bollworm the yield of cotton had fallen from its maximum in 1897 of 5·80 kantars to a minimnm in 1909 of 31·3 kantars. Since the introduction of the pink bollworm the yield has been higher than that of 1909 in each year except in 1916, when it was slightly less.

In 1909 the exceptionally low yield was largely due to the very high and very early Nile flood, which caused a saturation of the soil in Lower Egypt, and resulted in the shedding of a very large proportion of the bolls. In Upper Egypt the basins

were filled, and the development of the crop checked at an unusually early date.

In 1914 the yield was also small. This is very largely accounted for directly as a result of the outbreak of War. The cotton-market was demoralised, money became very tight, and a very considerable amount of cotton was not reaped, being allowed to remain on the plants. The yield in 1916 was also small. This is probably largely due to unfavourable weather conditions in the early part of the crop season, when a period of excessive heat was experienced ; this being followed by heavy applications of water caused enormous flower and boll-shedding, which resulted in a loss of a very considerale portion of the first picking of the crop.

It will be seen from this that an attempt to arrive at the amount of damage done by the pink bollworm by using the figures showing average yield is not likely to be convincing. If the period for which we have figures be divided into four-year intervals, and the mean average yields for each of these periods be taken under consideration, we see that the downward tendency is shown in each of these periods except in that for 1910-13, when there was a slight increase. (See Table VI.) This is the period during which pink bollworm was first discovered and became a serious pest in the country. The last of these periods (1914-17) shows a further falling off, the figure being lower than that of any other period except that for 1906-9, which was previous to the advent of the pink bollworm. It must be remembered that the crops of 1914 and 1916 which suffered from the causes mentioned in the preceding paragraph were included in this time.

The figures given in Table I are of interest in this connexion, and should be referred to in addition to those presented in Table VII.

Table VII.

SHOWING THE MEAN AVERAGE YIELD OF COTTON PER FEDDAN IN EGYPT IN FOUR-YEAR PERIODS FROM 1894-1915.

Four-year period.	Mean average yield, kantars per feddan.	
1894-1897	5 29	
1898-1901	5 04	
1902-1905	4·41	
1906-1909	4 09	
1910-1913	4·42	Pink bollworm in Egypt.
1914-1917	4·13	

Mr. Willcocks (32) in estimating the loss in yield per feddan, makes careful calculations based on the yield from 204 plants at Bahtim in 1914, and by weighing the cotton picked, counting

attacked bolls, and estimating the loss from those bolls which were attacked and still produced some cotton, he estimated that the loss amounted to about 44 per cent. of the possible crop.

The field in which these plants grew yielded in actual crop picked at the rate of 5·11 kantars per feddan. He calculated that if there had been no pink bollworm attack, all other things being equal, the yield from this field would have been at the rate of 9·29 kantars per feddan. The loss from bollworms was estimated at 4·13 kantars and, of this, 4·01 kantars was considered to be directly due to the action of the pink bollworm.

While these figures are accurate for the 204 plants on which the calculations are based, and for the fields in which they were grown, they cannot be taken as a basis on which to compute the loss due to pink bollworm attack on a large scale. If it is argued that this condition was representative of the whole of Egypt, and that the crop recorded for 1914 was only 56 per cent. of the crop which would have been reaped but for the pink bollworm, some extraordinary figures are produced. The crop for this year is given as being 6,450,000 kantars, which was produced at the rate of 3·67 kantars per feddan. If, according to this argument, pink bollworm injury had been eliminated, the enormous crop of 11,610,000 kantars should have been produced in that year, and the rate of yield would have been 6·61 kantars per feddan.

These figures are considerably larger than those for the largest crop (in 1913), and the highest average yield, (in 1897) ever recorded for the crop of Egypt.

It would seem that this line of investigation does not give a correct idea of the actual loss in crop by the pink bollworm, any more than those derived from the comparison of the avarage yeilds per feddan.

The period of eight years (1910-17 inclusive) is the time during which the pink bollworm has been affecting the cotton crop in Egypt. Some of the conditions under which has cotton has been growing during that time may be taken under consideration for the purpose of getting an idea of the influences affecting the yield, and the amount of damage that may fairly be charged aganist the pink bollworm.

The attacks of the ordinary bollworm have been growing less year by year since the pink bollworm appeared on the scene; there have been no serious attacks by the cotton worm during this time which can be considered as having materially affected the crop as a whole. The cotton bug and cotton aphis have occurred at much the same rate as in former years. As far as the yields during this time have been affected by insects, the pink bollworm must be considered as being responsible.

In 1911, Sakellaridis cotton first came into general cultivation, and from that time it has occupied an ever increasingly important place in the cotton industry. In 1917, this variety occupied 68 per cent. of the cotton area in Egypt. This variety is not so prolific as some of the varieties which it has replaced, and its substitution has probably produced a general effect towards reducing, or at least keeping down the average rate of yield. A comparison of the yields in Upper and Lower Egypt

for twenty years is of interest in this connexion. In Upper Egypt, Ashmuni has been the variety principally cultivated for the whole of this time and, as the figures in Table VIII show, the average yields have been better maintained in that portion of the country than in the Delta where the varieties cultivated have undergone many changes. In comparing these figures it is noticeable that in the Delta, the mean of the average yields, for the first of the five-year periods during this time is the highest while in the case of Upper Egypt the last five-year period presents the highest figure. This it will be noted, is the period during which the pink bollworm has been known as a pest.

TABLE VIII.

SHOWING AVERAGE YIELDS IN UPPER AND LOWER EGYPT IN EACH YEAR 1897-1916, AND THE FIVE-YEAR MEANS OF THESE AVERAGES

Year.	Yearly averages, kantars per feddan.		Five year means, kantars per feddan.	
	Upper Egypt.	Lower Egypt.	Upper Egypt.	Lower Egypt.
1897	4·7	5·9		
1898	3·9	5·1		
1899	4·5	5·7	4·10	5·26
1900	4·1	4·4		
1901	3·1	5·2		
1902	4 3	4·6		
1903	4·8	4·9		
1904	4 6	4·3	4·16	4·48
1905	3·2	3·9		
1906	3·9	4·7		
1907	4·5	4·5		
1908	3·1	4·2		
1909	4·0	2 9	4·10	4·12
1910	4·7	4·6		
1911	4·2	4·4		
1912	4·8	4·4		
1913	4·5	4·7		
1914	3·9	3·7	4·22	3·94
1915	4·4	4·0		
1916	3·5	2·9		

The pink bollworm attack increases in severity as the season progresses. According to Dr. Gough [33] the records show that in 1916, in July, 6 per cent. of the green bolls were infested by the pink bollworm, in August 32 per cent., in September about 80 per cent. and in October about 85 per cent. of all the green bolls remaining on the plants in the fields were attacked.

Early in the season, only one pink bollworm is commonly found in an infested boll ; later, it is more usual to find several larvae in some of the bolls; and toward the end of the season

every infested boll will be almost certain to contain more than one larva, and in some instances there may be as many as ten or twelve of these insects in one boll.

According to Gough, the infestation may amount to as much as 30 per cent. of the bolls on the plant by the first week in September. At this time, the damage done by the pink bollworm will usually amount to less than half the contents of one lock or division of the boll. As there are usually three locks, the damage is at that rate less than one-sixth of the contents of the boll, and it is probably nearer one eighth. The bolls which are infested at this time, the end of September, may be taken as the bolls from which the first picking will be obtained. Taking the figures given above of 30 per cent. of the bolls infested and of this 30 per cent., about one eighth being lost, we have a percentage on the total number of bolls of 3·75 which represents the loss due to pink bollworm attack in the first picking.

In the second picking, the infested bolls may amount to 80 per cent. of the total, some of which are completely destroyed, and some only slightly injured. If, for the sake of argument, it is assumed that 50 per cent. of all the second picking has been lost, it will probably be not far from the mark.

The third picking may be taken as being entirely destroyed by the action of the pink bollworm.

During the past few years with the varieties that have been cultivated, and the agricultural conditions which prevailed, it may be considered that about 80 per cent. of the crop was developed for the first picking, about 12 per cent. for the second, and the remaining 8 per cent. for the third.

If the rate of loss given in the preceding paragraph is applied to these figures, the following probable percentages of loss in the crop are shown :—

80 per cent.	× 3·75 per cent.	= 3 per cent	loss in first picking
12 ,,	× 50 ,,	= 6 ,,	= ,, ,, second ,,
8 ,,	× 100 ,,	= 8 ,,	= ,, ,, third ,,
or a loss of		17 ,,	of the probable crop

due to pink bollworm.

If a loss due to pink bollworm attack of 17 per cent. of the crop was experienced in the years 1916 and 1917, the figures given in Table IX would represent 83 per cent. the possible crop. It may be assumed that if the influence of this insect had been entirely removed in those two years, the crops would have been proportionately increased, according to the following figures: the crop for 1916 would have amounted to 6,096,854 kantars at the average rate of 3.67 kantars per feddan, and for 1917, 7,600,000 kantars at 4·53 kantars per feddan. According to this calculation, the loss in crop for 1916 amounted to 1,036,500 kantars, the reduction in the rate of yield being 0 63 kantars per feddan, while for 1917 the loss in crop would have been 1,304,000 kantars, the rate in yield being reduced in this year by 0·77 kantars per feddan.

Table IX.

TABLE SHOWING THE AMOUNT OF THE COTTON CROPS AND THE AVERAGE YIELDS PER FEDDAN. 1894-1918.

Year.	Cotton crop kantars.	Average yield, kantars per feddan.
1894	4,619,233	4·78
1895	5,256,128	5·27
1896	5,879,479	5·60
1897	6,543,628	5·80
1898	5,588,816	4·98
1899	6,509,645	5·64
1900	5,435,480	4·42
1901	6,369,911	5·10
1902	5,838,790	4 58
1903	6,508 947	4·88
1904	6,313,370	4·39
1905	5,959,883	3·80
1906	6,949,383	4·61
1907	7,234,669	4 51
1908	6,751,133	4·12
1909	5,000,772	3·13
1910	7,505,072	4·57
1911	7,386 328	4·31
1912	7,499,241	4·35
1913	7,663,801	4·45
1914	6,450 592	3·67
1915	4,806,331	4·05
1916	5,060 389	3·06
1917	6,308,000	3 76

In the case of the 1916 crop, the difference would not be as striking, because even with the correction made, the average yield 3 67 would still be a low one. It must be remembered, however, that the crop of 1916 suffered very heavy loss from unfavourable climatic conditions in the early part of the year. That this was recognized by the Ministry of Agriculture of the Egyptian Government is shown by the statement in the *Monthly Return* dated September 30, 1916, reviewing the cotton industry of the country, as follows: 'On the whole, the yield of the crop this year is likely to be appreciably below the average, the main causes being the abnormally excessive and continued heat in June, followed generally by too copius watering which prevented the formation of lower branch bolls: the quick maturity of middle bolls before attaining the maxium size; and the damaged condition of the upper, or late bolls by the pink bollworm.'

If the loss on the recent crops due to pink bol worm attacks amounted to 17 per cent., then the crop obtained was only 83 per cent. of what it should have been if there had been no pink bollworm attack. Examining the figures in the light of this assumption, it is seen that a correction to offset the loss of 17

per cent, would raise the figures for the amount of the crop and the average yield to the level some twelve to fifteen years earlier.

Table X gives figures to show what would have been the amount of the cotton crop and the average yield if the loss of 17 per cent. due to pink boll worm were eliminated in the years 1911–18, with a sliding scale of correction for loss in the years 1911, 1912 and 1913 as follows: 1911, 5 per cent.; 1912, 10 per cent.; 1913, 15 per cent; and subsequent years 17 per cent.

Table X.

TABLE SHOWING THE POSSIBLE YIELDS OF COTTON AND THE AVERAGE YIELDS WITH THE SUPPOSED LOSS FROM PINK BOLLWORM ELIMINATED IN THE YEARS 1911-16.

Year.	Cotton crop, kantars.	Average yield, kantars per feddans.
1911	7,775,052	4·53
1912	8,332,604	4·83
1913	9,016,236	5·23
1914	7,771,797	4·42
1915	5,790,760	4·88
1916	6,096,854	3·67

Note. The mean of these average yields is 4·59 kantars per feddan. They might be compared with those for 1898 to 1903, when the mean for the average yields was 4·76 kantars.

Although the estimate of 17 per cent., loss, due to pink bollworm, is less than that of Willcocks, it is probably not far from correct. It must, however, be too high rather than too low, for it is not likely that the elimination of one factor could offset to such an extent, and so suddenly, the downward tendency in the average yields which had been so persistent and so conspicuous a feature in the cotton industry during the twelve to fifteen years previous to the advent of the pink bollworm.

Infestation of Green Bolls.

The infestation of the green bolls on the cotton plant by the pink bollworm was investigated by Gough ([33]) who found that about 5 per cent. of the green bolls on the plants in July 1916 were infested, and this percentage rose to about 80 per cent. in October. He published an interesting table showing the number of green bolls per 1,000 plants and the number of those infested.

Table XI.

SHOWING THE NUMBER OF GREEN BOLLS PER 1,000 PLANTS AND THE NUMBER OF BOLLS INFESTED BY PINK BOLLWORM IN 1916.

1916. Week.	Green bolls per 1,000 plants. Number of bolls	Bolls infested.
July 8–14	5,472	274
„ 15–21	7,366	295
„ 22–28	7,900	395
„ 29–Aug. 4	8,271	414
Aug. 5–11	8,787	791
„ 12–18	8,732	1,397
„ 19–25	9,253	1,728
„ 26–Sept. 1	10,024	2,706
Sept. 2–8	10,168	4,067
„ 9–15	8,818	4,144
„ 16–22	7,480	4,488
„ 23–29	5,156	3,506

This table shows the number of bolls attacked, but does not indicate the degree of the infestation.

The present writer had under observation two lots of green bolls collected in 1917—one on September 16 after the first picking had been taken off the other on October 22, after the second picking had been harvested. These two lots were about equal in numbers of bolls, and were estimated to contain about 6,500 bolls each.

The first lot of about 6,500 bolls gave a moth emergence of 4,645 in October and 125 in the first half of November. A total of 5,770 or about eighty-nine moths per 100 bolls. Examination of these bolls during the latter part of November revealed the presence of living larvae at the rate of eighty-five larvae per 100 bolls, making a total of about 174 insects per 100 green bolls, at the end of the first picking, about the middle of September. This does not take into account the number of full-grown larvae that, without doubt left the bolls after they were collected and were lost before the bolls arrived at the insectary. The bolls were collected on September 16. Moths began to emerge on October 1. Thus the emergences for the two weeks which elapsed between the collecting and the record of October 1, were lost. If the larvae were completing their development during that time as rapidly as in the following two weeks, something like 2,500 insects escaped. An allowance of a loss of thirty to forty larvae per 100 bolls would bring the infestation to about 200 pink bollworms per 100 bolls at the time of collecting.

About 50 per cent. of the bolls were infested, and this with the figures just given, make an infestation amounting to about 400 pink bollworms per 100 infested bolls, or four insects in each attacked boll.

The second lot of green bolls collected on October 22 after the second picking was taken off, gave very few moth emergences

until about the middle of November. During the first half of November, an examination of 500 bolls gave the following figures: 445 bolls or about 90 per cent., contained living larvae, and these numbered 1,110. This amounted to 220 larvae per 100 bolls, and about 250 per 100 attacked bolls. These bolls produced moths at the rate of twenty-two per 100 bolls during November, leaving in the bolls at the end of the month, when the observations were brought to a finish, more larvae at the rate of nearly 200 per 100 bolls, many if not most of which were resting stage larvae

This gives a most striking illustration of the danger of infestation of the next crop from the old bolls This heap of 6,500 green bolls contained about 13,000 living larvae at the end of November, of which at least one half, probably many more than one half, were resting larvae which might emerge and infest the cotton crop in the next season, and even in the second season, if they had not been properly disposed of.

THE EMERGENCE OF THE MOTHS.

It has already been indicated that throughout the cotton-growing season the pink bollworm is developing rapidly. The infestation, which is at first sight, increases at an astonishing rate as the season progresses. In May and June, when the first flowers and young bolls appear, the insect is so rare that it can scarcely be found in the fields, while toward the end of the season nearly all the bolls are infested, many of them containing several larvae.

The first infestation results from the egg-laying of moths developing from over-wintering larvae, i.e. resting stage larvae. These may have been brought to the field in the seed used for planting, or they may have emerged from seed kept in seed-stores, or the larvae may have hibernated in old bolls scattered on the ground, buried in the soil, or attached to the old plants kept in the villages, at pumping stations, or other similar places for fuel.

The first attack on growing cotton in the field appears to occur in May or early June. Further attacks and increased severity of infestation result from the rapid increase in numbers, as these first larvae complete their development, pass through the pupa stage, and emerge as moths.

One generation follows another every four or five weeks during the summer months each generation containing perhaps 100 times as many individuals as the one before it.

At the same time other moths are coming into the fields and depositing additional supplies of eggs, thus greatly accelerating the rate of increase. These moths also develop from resting stage larvae which have remained quiescent since the previous season, or in some instances since the season previous to that; for, it is easily possible that larvae which developed in the cotton of the 1915 crop, remained dormant through the whole of the year 1916, and appeared as moths in the summer of 1917, say, in June, July, or even in August.

Willcocks (32) published figures with regard to the emergence of moths from 50,000 bolls kept in trays in a breeding cage.

These figures have been brought together in Table XII, and they show the emergences of moths per month from November 1913 to August 1915. These bolls were collected in the field in November, and for twenty-two months they continued to give moth emergences, February and March 1913, and March 1914 being the only months during that time when no emergences were recorded. It will be seen that in 1914, in the months of July, August and September, very large numbers of moths emerged. and that another period of active emergence occurred in May, June, and July in the following year. The present writer obtained similar results from about 60,000 bolls collected in the field in the third week of November 1916. The records extend over a period of one year. From this lot of bolls the most active emergence is recorded for the months of April and May. There was a falling off during June and July, but the numbers recorded during these two months do not show the same contrast as the numbers in Willcocks's table. The figures are larger for the months of August, September, and October. It might be safer to consider the whole period – April to October inclusive – as the period of high emergences, and that in 1914 some condition operated to retard the beginning of the season for emergence until July, as shown by Willcocks's figures ; or that in 1917 that something caused an early emergence which gave large figures for the monthsof April, May, and June, as shown in Table XI.

TABLE XII.

SHOWING EMERGENCES OF MOTHS FROM BOLLS AS RECORDED BY MR. F. C. WILCOCKS.

Year.	Month.	Number of moths.
1913.	November	77
	December	2,184
1914.	January	175
	February	
	March	0
	April	5
	May	9
	June	59
	July	1,123
	August	2,536
	September	2,411
	October	236
	November	15
	December	8
1915.	January	4
	February	3
	March	0
	April	24
	May	159
	June	207
	July	80
	August	14

These figures show that there is a tendency for an enormous rate of emergence of moths developed from resting stage larvae during the months when cotton is growing in the field and producing flowers and bolls.

Resting stage larvae in cotton seeds in the seed-stores emerge at about the same time as those in seeds in old bolls.

There can be no doubt that a very large proportion of the infestation in the cotton fields in Egypt in past seasons, has been due to the invasion by moths emerging from cotton seed and old bolls, during the time when the cotton is growing, and actively producing new bolls.

Table XIII.

SHOWING EMERGENCES OF MOTHS FROM BOLLS. (H.A.B.)

Year.	Month.	Number of moths.
1916.	December	155
1917.	January	37
	February	16
	March	40
	April	2,602
	May	846
	June	119
	July	154
	August	614
	September	515
	October	292

Attraction of the Pink Bollworm to Light.

Several writers on the habits of the pink bollworm have stated that the the moths are attracted to light, and light traps have been recomended for the control of the insect in the field. Busck (36), however, states positively, that the pink bollworm is not attracted to light. Willcocks (32) found in Egypt that both the male and female moths came readily to light; of a total catch of 5,856 moths 58 per cent were males, and 42 per cent. females. In another place (35) the same author publishes a table showing the number of pink bollworm moths and Earias bollworm moths caught per week in light traps, Fr m September 1 to November 2, 1916. The figures relating to the pink bollworm are given herewith :—

Week ending.		
September 7		884 moths
„ 14	(full moon, Sept. 11)	451 „
„ 21		3,052 „
„ 28		3,132 „
October 5		2,282 „
„ 12	(„ „ Oct. 11)	140 „
„ 19		186 „
„ 26		178 „
November 2		112 „

The present writer found that light traps could be successfully used for capturing moths emerging from bolls in the insectary.

Reference has already been made to the number of the moths emerging from some 60,000 bolls which were kept under observation. These bolls were collected in November 1916 and placed in a heap on the ground in one of the rooms of the insectary at the Ministry of Agriculture, Cario. From December 1916, to the end of March 1917, the record of emergences are based on the moths which it was possible to capture during the day in this room. A few were caught in the early morning clinging to the wire which formed the sides and the roof of the insectary, and others were caught by searching amongst the top layers in the heap of bolls. This was very unsatisfactory, and it is probable that many individuals escaped. The catch for the whole of March amounted to forty moths. On April, a light trap, consisting of an electric bulb, suspended over a pan of water to which a few drops of kerosene had been added, was installed in this room. On the first night in which the trap was in use, the catch amounted to sixty the catch for the month being 2,600, and for the remainder of the season the emergences recorded were based entirely on captures by this trap. In June 1917, a similar trap was established in a large cotton-seed store in Alexandria,and observations were made on the catches in this trap until November 20, 1917. During the month of September, the number emergences was very large, the numbers one night falling just short of 8,000. On several nights, when it was known that the light was not burning, the catches were very small. For instance, on the morn-September 19, only one moth was found in the trap. On the previous morning the catch had amounted to 2,222, while on the day following, the catch numbered 881. Again on October 8, only one moth was found in the trap, whereas on the day before, and the day after that date the numbers were thirty-eight and fifty respectively. A very striking instance of this is seen in comparing the catch of September 12,which amounted to eight moths with that of September 11, when 5,500 were counted, and that of September 13, when the catch was 6,060.

Table XIV.

SHOWING NUMBERS OF PINK BOLLWORM MOTHS CAPTURED IN LIGHT TRAPS, IN COTTON-SEED STORE AT ALEXANDRIA DURING SEPTEMBER AND OCTOBER, 1916.

Day of month.	September.	October.
1	32	204
2	265 (2–3)	12
3		16
4	191	19
5	184	24
6	318	26
7	943	38
8	2,470	1
9	4,500	50
10	7,960	42
11	5,500	87
12	8	44
13	6,060	52
14	5,760	65
15	2,800	103
16	5,500	–
17	–	65
18	2,222	34
19	1	34
20	881	23
21	1,403	14
22	1,524	48
23	1,010	26
24	985	56
25	710	160
26	227	154
27	–	120
28	–	126
29	–	95
30	–	56
31	×	56

The facts recorded are evidence that the pink bollworm is attracted to light in Egypt, and this attraction is exercised by lights in the field, in the large warehouse where cotton seed was stored, and in the small room of the insectary.

In connexion with the obtaining of records on the moth emergences, observations were made as to the hours when the moths come most readily to light.

On September 16, 1917, about 6,500 green bolls were collected at Gemaiza, just after the first picking of cotton had been taken off. These bolls were thrown in a heap on the ground in a room of the insecretary at the Ministry of Agriculture, Cairo, and moths began to emerge in about two weeks. The observations on the hours of moth activity were made in two periods October 6-9 inclusive, and October 16-19 inclusive.

On two nights the light was turned on at 5 o'clock; there was no catch during the first hour, the first moths arriving at the light almost exactly at six o'clock. At that time of the year the sun sets at about 6 o'clock at Cairo.

On two nights the light was turned on at 6 o'clock, on two nights at 7 and on two nights at 8. On all these occasions moths arrived at the light immediately.

The accompanying table shows the hours at which the moths came to light. Observations were made until 10 o'clock, on four nights, and until 9 on the other four, but the light burned until morning. The column headed 'Morning' shows the numbers of moths found in the basinthe next morning. These numbers represent the catch after observations ceased at 10 o'clock on the first four nights, and after 9 o'clock on the second four nights. It will be noticed that the catches on the first night of each of these periods are very large. This is because on several preceding nights there was no light trap in this room, and these large numbers included moths that had emerged on previous nights.

These observations indicate that the pink bollworm is a dusk flier and that activity is greatest during a short period just after sunset.

It was noticed in connexion with these observations in the insectary that, no matter how large the catch, there were always some moths which did not come to the light, and that moths leaving the heap of bolls often flew directly past the light to the top or sides of the room. It may be that they do not come to light at all, or perhaps only sparingly on the first night of their winged existence, and that their impulse on emerging is to make for the open field.

TABLE XV.

Dates.	The hour 6-7.	The hour 7-8.	The hour 8 9.	The hour 9-10.	From last count until morning.	Total catch for the night.
Oct. 6	884	141	49	94	55	1,223
,, 7*	345	97	30	18	30	520
,, 8	...	319	46	34	21	420
,, 9	...	...	279	19	10	308
,, 16	1,099	57	22	...	41	1,219
,, 17	...	...	157	...	27	184
,, 18*	90	57	22	...	32	201
,, 19	...	148	35	...	20	203

Note. Lights were turned on as follows:—

7th and 18th	at 5 o'clock.
6 ,, ,, 16 ,,	,, 6 ,,
8 ,, ,, 19 ,,	,, 7 ,,
9 ,, ,, 17 ,,	,, 8 ,,

Observations ceased for the night at 10 o'clock on the 6th to 9th, and at 9 o'clock on the 16th to 19th.

*On these nights light was turned on at 5 o'clock, but there were no catches before 6 o'clock.

The Relative Abundance of the Ordinary Bollworm and the Pink Bollworm in Recent Years.

The cotton bollworm (*Earias insulana*) was formerly the most important insect pest of cotton in Egypt. Within the past few years the pink bollworm has become extremely abundant, and has assumed the position of a pest of the first importance. At the same time the Earias bollworm has very much decreased in numbers, until it has become a pest of very little importance. From the records obtained by Willcocks, Dudgeon (40) was able to give a table making comparisons between the attacks of this insect in the same localities in the years 1912 and 1913. From these records it is seen that in 1912, the percentage of bolls attacked ranged from 11 to 44, and in 1913 from 0 to 11 per cent. In no instance was there any increase in the percentage attacked in 1913 over the figures for 1912.

In 1916 and 1917, the percentage of bolls attacked by Earias was very small. In 1916, Gough estimated, after an examination of many thousands of bolls, that the attack reached its maximum at the end of October and the beginning of November, at which time the infestation was as follows:—

Lower	Egypt	7 per cent.
Middle	Egypt	11 ,, ,,
Upper	Egypt	7 ,, ,,
All	Egypt	8 ,, ,,

In the *Monthly Bulletin* on the condition of crops in Egypt, the figures relating to the Earias attacks in 1917 indicated that less than 5 per cent. of the bolls, were affected during July, August and September, which is about the same as for the same period of 1916.

The difference between the rate of attack in 1912 and in 1917 shows clearly that this insect had decreased in numbers. This was probably due to two causes. Earias being an indigenous insect probably varies in abundance from time to time as any native insect or pest of long standing in any country is known to do. This is probably the result of the relation which exists between the pest and its natural enemies. Another reason may be found in the attempts that have been made to compel the destruction of old cotton plants. Legislation was put in force in 1909 when, in certain localities at least, the provisions of the law were complied with, and cotton plants were cut or pulled at an earlier date than in previous years.

The ravages of the pink bollworm were such that other laws were passed and more complete destruction of bollworm infested material was provided for. This later legislation was principally directed to the control of pink bollworm, but there can be no doubt that the first result of the operation of the law was to decrease, very greatly, the ordinary bollworm.

Table XIV.

TABLE SHOWING PERCENTAGE OF ATTACK OF PINK BOLLWORM IN BOLLS.

Bolls collected in Lower Egypt during September and examined in December.

Year.		Bolls examined.	Bolls attacked.	Per cent. attacked.
1912	...	2,337	171	7
1913	...	3,472	1,494	43
1914	...	1,295	857	68

Bolls collected in Upper Egypt in November and examined in December.

1912	...	788	15	2
1913	...	887	153	17
1914	...	912	247	27

The tables presented herewith give figures obtained by Mr. Willcocks as to the percentage of bolls attacked by pink bollworm in the fields in 1912, 1913 and 1914. They show that in the Delta in 1914 68 per cent. infestation was recorded at the end of September while in Upper Egypt in the same year only 27 per cent. infestation was recorded in November.

According to figures published by the Ministry of Agriculture in the *Monthly Bulletin* the infestation in 1917 in both these sections of the country, amounted to from 66 to 69 per cent. in September.

From this it is seen that a percentage of bolls infested in September was the same in the Delta in 1914 as in 1917, while in Upper Egypt there had been a very considerable increase, until it reaches the rate recorded in the Delta.

The fact that the rate of infestation in the fields at the end of September has not increased in the Delta during the period 1914-1917 suggests that the pink bollworm reached the maximum of its attacks in the former of these years. That is to say, in four years from its first discovery it may have shown the worst it can do. In Upper Egypt this percentage of infestation (65 to 70) was reached in four years after the pest was known to be generally distributed in this part of the country.

If this assumption is true and the pink bollworm develops in the first four or five years after its introduction into a locality to its maximum strength, then every step in control measures ought to produce results sufficiently obvious to indicate whether such measures are likely to be satisfactory.

The Natural Enemies of the Pink Bollworm.

The natural enemies of the pink bollworm have not been found to be of any considerable value in controlling this insect. Several parasitic and predaceous enemies have been found to attack the pink bollworm but either from their limited numbers

or owing to the time at which they occur they exercise very little influence on the severity of the pink bollworm attack

The most important of these natural enemies appears to be the predaceous Pediculoides (*Pediculoides ventricosus*). This mite attacks pink bollworms and destroys very large numbers, but these attacks come very late in the season. Cotton seed and seed cotton which have been stored for some months are liable to be thoroughly infested by this mite, and in June and July seed from the previous year's crop is liable to be so thoroughly infested that a very large percentage of the pink bollworms are killed.

If the cotton is ginned within a short time after being harvested, and the seed is treated as it leaves the gin there will be no necessity for the control by Pediculoides. An abundance of Pediculoides in cotton seed is of doubtful value unless it can be shown that it exercises real useful control over the pink bollworm, because it attacks human beings, producing very serious irritation of the skin, and cargoes of cotton seed containing this mite in abundance are discriminated against by the labourers, and the cost of handling is greatly increased [18]).

There are several hymenopterous insects which occur as parasites of the pink bollworm. None of these however act as a satisfactory check on the increase of the pest. The pink bollworm is so thoroughly protected from attacks of its natural enemies so long as it infests green bolls that they seem unable to make any headway against it. It is only late in the season when there are a good many open bolls in the field that the parasites are able to increase rapidly, and by this time the damage to the current crops has been done. The parasites could not be depended upon to exercise sufficient control over the insects which provide for the following season's infestations of pink bollworms, and consequently they do not save the necessity for destruction by artificial means. Artificial means of an efficient sort being provided, the action of the parasites becomes almost nil.

The great hope in this connexion is that an egg parasite may make its appearance which will attack the pink bollworm egg in the field and exercise a satisfactory degree of control over the pest.

The Control of the Pink Bollworm.

The control of the pink bollworm in Egypt depends largely on the destruction of the larvae, at the end of the season. These larvae are in the cotton seed ; in the cotton seed which remains in the field in green and dry bolls, and in that which has been removed from the field in the harvesting of the crop. The problem of control is therefore divided into two parts, one which has to do with the destruction of infested material in the field, and the other which deals with the treatment of cotton seed for the destruction of the larvae contained in it.

Destruction of Bolls in the Field.

The bollworm campaigns of 1916 and 1917 were conducted as field campaigns, and were regulated according to the provi-

sions of Law No. 17 of 1916, and the amendment Law No. 12 of 1917. The object of these campaigns was to insure the destruction as far as possible of the infested material left in the field at the end of the the cotton season. The Law provided that all cotton plants should be pulled or cut on or before a certain date, and that all the bolls should be cleaned from the plants, and all fallen bolls gathered up from the ground in the fields and burnt before another fixed date. No cotton sticks were to be permitted to be removed from the field until they were thoroughly clean and no sticks were to be allowed to be taken into any of the villages until all sticks were cleaned and all infested material in the field destroyed. It was required also that all cotton sticks, bolls, etc. must be cleaned out of the villages and burnt before any similar material might be brought in from the fields.

The regulations at first in force required that the bolls should be cleaned from the standing cotton plants and that all fallen bolls must be cleaned up from the ground before the plants were pulled or cut. Experience has shown, however, that the most satisfactory method is to allow the cotton plants to be cut or pulled, to be removed from the fields to some convenient place for cleaning, preferably near the villages, and then thoroughly cleaned and stacked with the tips all one way for easy inspection. When all the sticks belonging to any village are found to be clean then their admission into the village may be permitted, or if they are not all cleaned by the date fixed then they may be inspected, clean ones admitted to the village, and others burnt or otherwise disposed of.

Always before allowing the sticks to be taken into the villages these should be carefully inspeccted for any old cotton which may have been left over from the previous season. This provision is important only when there is doubt as to the cleanliness of sticks admitted in previous years.

On account of the scarcity of fuel in Egypt cotton sticks have a very considerable value in that country. The loss in fuel in the cotton plants that were burned as penalty for contraventions of the bollworms law in 1916 was about £87,000 reckoned at £1 per ton. In 1917, an endeavour was made to avoid enforcing the provisions of this law as far as possible, and while this resulted in some slacking off of the efficiency of the bollworms campaign, the efforts that were made resulted in a good deal of benefit. Permits were given for removing the plants from the field, and cleaning them in the village 'gurns.' Permits were also given freely for the removal of sticks to be used immediately as fuel in power plants, bakeries and anywhere where they were desired for immediate burning.

The methods of cleaning the sticks were various; in 1916 it was a common practice to beat off the bolls from the standing plant with cudgels. The bolls were collected by hand. In a few instances they were removed by the cotton plants being dragged through a form of comb or rake. (See plate.)

The beating off of the bolls was unsatisfactory because it meant that all the infested material had to be gathered up from the ground, and the number of bolls left behind was very great.

The picking of the bolls by hand was capable of being made very effective, but it was found to be rather expensive. Extensive trials of the comb or rake for cleaning indicate that this is likely to be the most useful method. This however involves the removal of the plants from the field to the cleaning ground, and when this is done various modifications of the rake method come naturally into play. For instance, at the village of Shamut where a very effective trial of the village 'gurn' system of cleaning was made in 1917 the peasants were found using rakes of various sorts the commonest of which were made by driving a few spikes into a log of wood. The plants were being whipped over the edge of a cart body, on the edges of the metal discs of the norag, or native thresher, and in one instance a cutlass or sabre had been fashioned from hard wood, and was being used with very good effect.

A machine for cleaning the bolls from the cotton plants was devised and given rather extensive trials in 1917. In principle it consisted of revolving drums set with spikes so spaced that when the cotton plants were introduced between them the bolls were whipped off by contact with the revolving spikes. In the early trials animal power applied by means of a sweep was used for driving the machine but it was capable of being driven by a motor. This machine promised to be very effective, and it was part of the plan of the promoters to conserve all the waste materials cleaned from the sticks including infested bolls by manufacturing it into briquettes for fuel. If this could be satisfactorily done the saving in fuel would be enormous.

Treatment of the Cotton Seed.

The larvae in the cotton seed which is removed from the field in the gathering of the crop constitutes a very large proportion of the pink bollworm population at the end of the cotton season. Many of these larvae are of the short cycles sort which will on becoming full-grown immediately proceed to pupate and come forth as moths. In the cotton stores where the seed cotton is held before ginning, and above all in the ginneries after the seed comes from the gins the larvae may be seen coming out and pupating. There is, however, in this seed a large number of resting stage larvae which are nature's provisions for carrying the life of the insect over a long unfavourable period such as that presented by the Egyptian winter.

After many experiments it has been found that the application of heat to infected cotton seed is a thoroughly satisfactory method of dealing with this insect. Storey's experiments (37) show that a temperature of 55° C. maintained for five minutes is sufficient to cause the death of pink bollworm larvae without injury to the germinating qualities of the seed. A Law was passed (No. 29, 1916) requiring all ginneries in Egypt to be equipped with machinery by September 1, 1917 for the application of heat for the destruction of the pink bollworm in the seed, but it was found impossible to enforce this law because of the difficulty of obtaining the necessary machinery.

When the bollworm campaign is in as thorough operation as possible the proportion of infested material which will escape destruction will be very small, and this, united with efficient treatment of the seed as it comes from the gin should very greatly reduce the severity of pink bollworm attacks in Egypt.

There is in addition a law which provides that no seed cotton or cotton seed may be stored except in a licensed warehouse between the dates of May 1 and August 1. Before a license will be issued to allow a building to be used for the storage of cotton or cotton seed such building must be protected at its doors, windows ventilators etc., so as to prevent the escape of any pink bollworm moths which may be developed from larvae in the seed.

In addition to these methods of dealing with the pink bollworm there are certain purely agricultural features which have a direct bearing on the severity of the attacks of this insect.

The important point in agricultural practice in this connexion is earliness; earliness in ripening the crop, earliness in the removal of the sticks from the field, and earliness in the treatment of the cotton seed as it leaves the gins.

Earliness in ripening the crop has been largely provided for in the very general cultivation of Sakel cotton. This variety produces a large proportion of its crop in its first and second pickings and consequently a larger proportion of its possible yield is obtained than would be the case with those varieties which formed the bulk of the crop a few years ago since these produced most of their crop in the second and the third pickings which are much more seriously attacked.

It is quite possible that other varieties may be developed which will possess this desired quality of earliness, and good yields to even a greater extent than Sakel.

Experiments which have been carried out on a fairly large scale indicate that early ripening can be induced by the manner of application of irrigation water. Messrs. Dudgeon and Cartwright (39)showed that by withholding water after a certain date the ripening of the crop could be forced forward considerably without loss in yield or deterioration in quality of the cotton obtained. (See plate.)

In addition to this they showed that by removing the tips of the shoots of the cotton plants in addition to withholding water not only did they force the ripening of the crop but they prevented the formation of new bolls and flowers so that when the crop was picked the number of bolls which might be infested by pink bollworm remaining on the plant was reduced to a minimum.

The practice of grazing herds of sheep and goats in the standing cotton after the crop is off is very useful, particularly if the flocks are large, and can be kept crowded on restricted areas until they have thoroughly cleaned the plants. There will probably be a few dry bolls on the plants which these animals will cut and eat, and a few scattered bolls on the ground which will require to be carefully cleaned up and disposed of.

Summary.

The control of the pink bollworm may be briefly summarized: it is essential that all infested materials left in the field at the end of the cotton season should be carefully collected and buried or otherwise disposed of so as to prevent development of the bollworms contained in them. All cotton should be ginned as soon as possible after b ing picked, and all cotton seed should be treated in some efficient manner for destroying the larvae in it. The crop should be ripened as early as possible and the infested material in the field dealt with immediately the crop is off. Earliness in ripening the crop may depend on the natural tendency of the variety cultivated and this tendency to earliness may be assisted by a proper method of dealing with irrigation. Topping the plants very greatly reduces the amount of boll material left in the fields at the end of the season. Sheep and goats are very useful for destroying by grazing bolls left in the fie'd.

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[Pages 189—292 issued 14th November, 1919.]

Fig. 1.
LEVELLING IN PREPARATION FOR PLANTING.

Fig. 2.
YOUNG COTTON.
The Soil Opens in Large Cracks After Irrigation.

Fig. 3.

YOUNG COTTON.

This Soil Has Been Worked Since Irrigation.

Fig. 4.

LABORERS HOEING COTTON.

Fig. 5.

PLANT OF ASHMUNI COTTON.

Fig. 6.

COTTON PLANT WHICH HAS BEEN TOPPED AND FROM WHICH WATER HAS BEEN WITHELD TO FORCE RIPENING.

Fig. 7.

COTTON PLANT NOT TOPPED WHICH RECEIVED USUAL WATER.

Note Flowers and Young Bolls.

Fig. 8.

SHEEP GRAZING GREEN BOLLS IN COTTON FIELD.

Fig. 9.

VILLAGE "GURN" WHERE COTTON STICKS ARE BEING CLEANED AND STACKED FOR INSPECTION.

Imperial Department of Agriculture

FOR THE WEST INDIES.

HEAD OFFICE—BARBADOS.

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